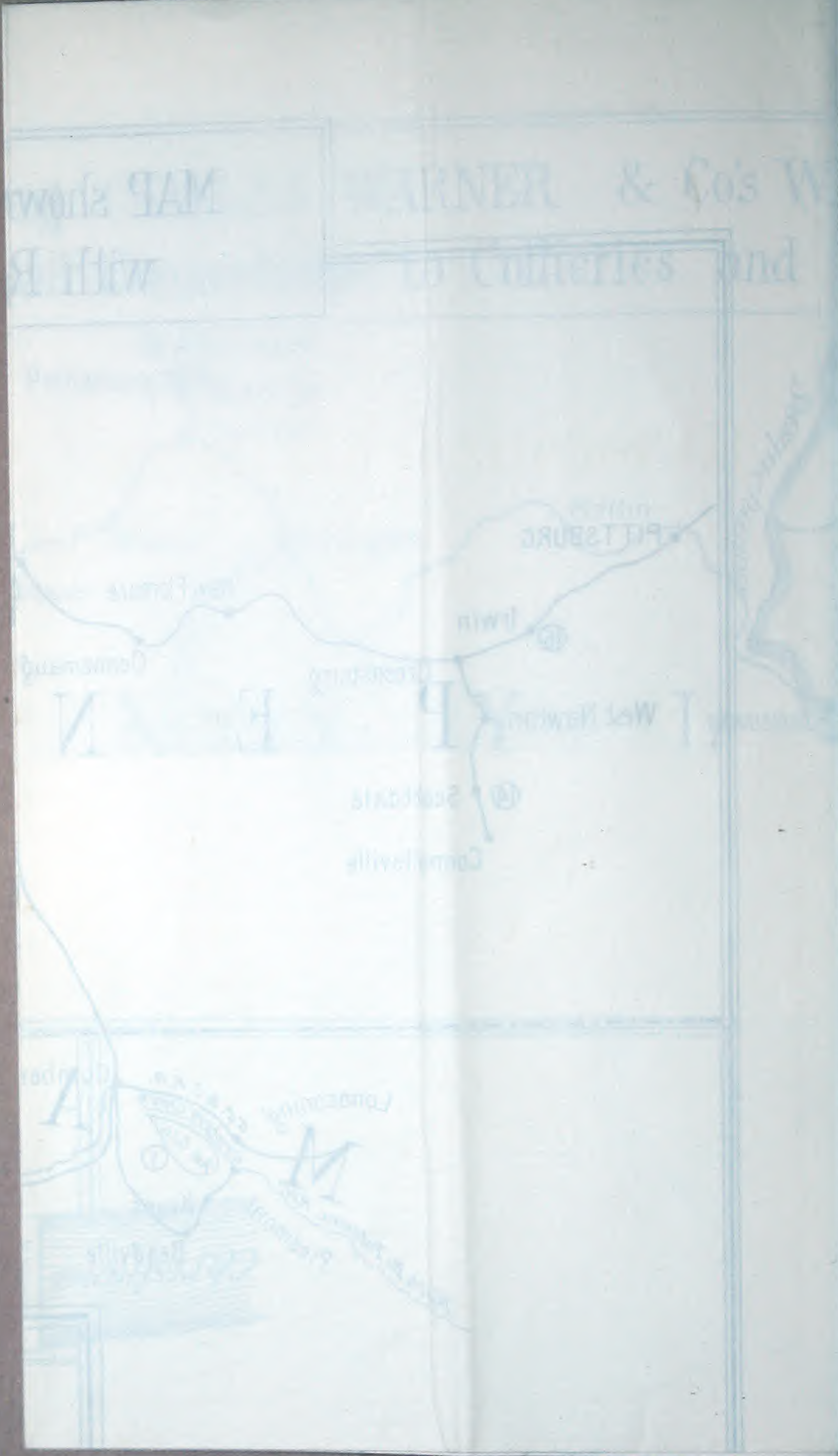
1497-3 L. M. Haupt
May 1, 07

COMPLIMENTS OF
CHARLES WARNER & CO.,
WILMINGTON, DEL.

Lime,
Hydraulic Cement,
Coal,
Transportation.


WARNER & Co's W
to Collieries and

LIME

AND

Hydraulic Cement,

THEIR USES,

AND HOW TO TREAT THEM.

TOGETHER WITH A

GENERAL TREATISE

ON

COAL, COKE AND TRANSPORTATION.

WILMINGTON:
THE JAMES & WEBB COMPANY.
1883.

To the Public.

The most emphatic evidence of appreciation tendered us by our friends since we added the Lime and Cement Departments to our business, is the rapid increase in patronage continuously bestowed upon us.

We consider that some return for this confidence and support should be made other than that based upon the ordinary routine of business transactions, and we have also been impressed with the fact that some account of the details of the Cement, Lime and Coal trade, and the development of Transportation Lines in this city, would be of interest not only to our customers, but to the general reader.

To this end, we have compiled from the best and most reliable sources the data contained in this pamphlet. It is not put forward in any sense as an original production, and we cheerfully bear testimony to the services rendered in

the work of compilation by the writings of such standard authors as Colonel Q. A. Gillmore, Franklin, Platt, John Fulton, M. E., and others in the departments of Cement, Coal, and Coke.

We trust that the hints we have been enabled to secure from these and other sources, may be of practical value to our patrons in securing economy and reliable service in matters of Building Material, Fuel, Transportation, &c., that would not under other circumstances have been suggested to them.

We remain respectfully,

CHARLES WARNER & CO.

Wilmington, Delaware, August, 1883.

Cement.

SECTION I.

Portland Cement.

Composition.—Mode of Manufacture.—Properties.—English, French, and German Cements.—The Native Product.—Methods of Testing.—Concrete.—Directions for Use.—Roman Cement.—Lime Used with Cement Always Detrimental.—Sharp Sand a Requisite to Good Work.

PORTLAND CEMENT.

The use of Portland Cement in the construction of buildings and public works is increasing so rapidly and the superiority of the article over all others, is so apparent, that no apology is needed for a somewhat lengthy notice of its manufacture. It is fortunate that the materials, from which it is made, are derived from inexhaustible sources of supply, the world over, although the occurrence of its components united in a single substance is strictly limited to a few areas in limestone regions.

Antiquity of Cements and Concretes.

The manufacture of cements and concretes was well understood by the Romans, and many of their most mag-

nificent public works, notably their military walls and aqueducts, attest the mastery they had gained over the subject, but the element of hydraulicity, or the property of hardening and setting under water, was only imperfectly developed in the products of their kilns.

Not till the year 1824, or some sixty years ago, was the process of manufacturing a true hydraulic cement discovered by the merest accident, but like many such discoveries it immediately received the widest development. Wm. J. Aspdin, the experimenter, did not achieve the gigantic fortune which has attended the labors of so many other makers of the article since his time, but his name will ever remain associated with a discovery of which the present century can but imperfectly demonstrate the importance.

The merits of Portland Cement are, however, already fully recognized by architects and engineers, and the manner in which the product of English, French, German and American factories have alike withstood the several tests, has conclusively established its value.

Chemical Composition.

Chemically speaking, it is a double silicate of lime and alumina, that is to say, a combination of lime bases or calcium, and alumina, or clay, with silicic acid or silica, the principal element in quartz and flint. The enduring quality of cement, which is one of its most valuable attributes, depends largely on the nature of its constituents. All three, lime, alumina and silica, will resist the most intense heat of a blast furnace, unchanged. One of them, silica, is unaffected by the most powerful acids, and in combination, these substances can be separated or changed only by the most powerful agencies which the chemist can bring to bear on them.

Cement Manufacture in England.

Up to a few years ago the bulk of the Portland Cement

used in this country was imported from England, where the manufacture was a gigantic monopoly, out of which the two leading firms engaged in it have accumulated enormous fortunes. The importations of the English product into this country still continue to a considerable extent, on account of the excellence of the manufactured article.

The source of supply is in the southeast of England, in the north of the County of Kent, within twenty miles of London and about two miles from Gravesend. Within the last few years a third factory has been started, in the same locality, and other factories are in operation in Essex. In the English manufacture the materials used are white chalk, (a rock very scantily developed in this country, but forming the subsoil in one-half of England,) and the alluvial mud of the Medway, a river which flows into the Thames about fifteen miles below Gravesend. This mud has a peculiar greasy, soapy feel, owing to the large proportion of alumina it contains. The chalk, which is a soft rock of snowy whiteness, belongs, in the locality of Gravesend, to the geological division known as Chalk-with-flints, from the number of large flint stones which are found in regular layers through its structure.

Process of Manufacture.

The process of manufacture involves the mixing of the chalk and clay in wash mills into a creamy consistency with the aid of water: the product which is known as "slurry" is dried by exposure in shallow receptacles in chambers heated by the waste gases of the furnaces and kilns and then burned at a fixed temperature into a scoriaceous mass, resembling pumice stone, to which the name of "clinker" is applied This "clinker" being dried, ground to powder and passed through sieves, furnishes the finished product, the Portland Cement of commerce. It is of a gray hue with a slight tinge of blue, the latter

being a criterion of the excellence of the article. The analysis of a good sample shows the following figures:

Lime - - -	68.11
Silica - - - -	20.67
Alumina - - -	10.43
Oxide of Iron - - -	0.87
	100.08 per cent.

The weight of cement is also a good index of its quality. A barrel of Portland Cement weighs over 400 lbs., contains about 3 1-2 bushels and measures loose about 4.25 cubic feet. Its tensile strength, the most valuable of all qualities, is estimated at resisting a strain of 470 lbs. to the square inch, or when seven months old of 155 tons to the square foot.

Chemical Changes.

Many important changes take place in the chalk and clay while passing through the various stages of the manufacture. The Gravesend chalk, which is a nearly pure carbonate of lime is found to contain 25 per cent of water, 0.45 per cent of silica, 0.63 per cent of alumina and 73.75 per cent carbonate of lime. With this there is usually mixed a portion of the lower, or grey chalk from the Medway, belonging to the lower section of the same geological stratum as the white chalk. It contains 25 per cent. of water, 4 per cent. of silica, 0.21 per cent. of alumina, 66 per cent. carbonate of lime, about 1 per cent. of oxide of iron and 2 per cent. of soda and alkali. The mud from the Medway contains 60 per cent. of water, 2 per cent. of organic matter, 28 per cent. of silica, 5 per cent. of alumina, 3 per cent. of oxide of iron, and about 2 per cent. of carbonate of lime and alkalies. The analysis of the mixture of chalk and clay used in the manufacture will, therefore, be nearly as follows; water, 35 per cent., organic matter, 0.60 per cent.,

silica, 8 per cent., alumina, 1.87 per cent., oxide of iron, 1 per cent., carbonate of lime, 53 per cent., and alkalies, 0.21 per cent. Apart from the chemical changes, therefore, thirty-five per cent. of water has to be got rid of.

Stages of the Manufacture.

The first stage of the manufacture has for its object, the bringing of the constituents into the state of an intimate mechanical mixture, whereby the subsequent operation of heat in decomposing and re-arranging the three principal elements is more radically favored. In the second process, when the "slurry" is pumped up and dried on the floors of the desiccating chambers, no chemical change takes place, but the superfluous or uncombined water is driven off. In the third process of burning the "slurry" into the clinkers, the following alterations are assumed to take place within the kilns; (a) the carbonic acid combined with the lime is driven off, (b) one portion of the lime combines with the silicic acid or silica supplied by the flinty matter in the chalk, while the excess of lime remains in a caustic state, (c) another portion of the silicic acid or silica, combines with the alumina in the clay, (d) the oxide of iron is reduced by the action of the coal in the furnace and the organic matter, to a lower oxide, which is known from observation of natural conglomerates, to be an important element in consolidating and giving strength to calcareous and flinty mixtures.

The extent to which the oxide of iron exerts its influence if at all upon the induration of hydraulic mortars is however a subject of controversy. In the cement of Vassey in France, which is of excellent quality, the percentage of oxide of iron is large, while there are many good cements in the United States which contain less than .02 per cent. of the iron oxide. The eminent French Chemist Vicat says that "it is difficult to attribute a useful influence to the peroxide of iron," while on the other hand

in a paper submitted to the Academy of Sciences at Paris in 1854, Messrs. Malaguti and Durcher stated that those cements which were reported as the best for resisting the destructive action of seawater always contained a notable quantity of peroxide of iron.

As the consumption of fuel is a large item in the cost of manufacturing cement, and as the repairs of the ovens, from the burning and buckling of plates and from displacement caused by expansion, amount to a charge, the attention of the manufacturer has been directed to utilizing the spent heat from the kilns for the purpose of drying the "slurry" so that each kiln in burning may dry a charge of slurry itself.

To this end the kiln is arched over and from the level of the top of the kiln a platform of concrete is carried the width of the kiln and of sufficient length to dry the required quantity of slurry, this length depending upon the system of drying employed. In some cases running kilns are used where, by means of an ingenious apparatus, fresh quantities of dried slurry and coke are introduced at the top while the calcined product or clinker is withdrawn at the bottom, much on the principle of the blast furnaces used in smelting iron. The action of these kilns is practically continuous, their use being intermitted only for the purpose of effecting necessary repairs.

The clinker, when burned should be of greenish black color, but there will always be a certain proportion in every kiln which is pink or yellow, and therefore under burned, and, this is loaded into the next kiln and burned again. If there is much dust the clinker is over clayed, and the resulting cement weak. Under-burned clinker slacks and heats when wetted, but this is not the case with well burned clinker.

When the clinker is drawn from the kiln it is wheeled on to a weighing machine and weighed. It is then thrown into a crusher and reduced to small cubes about two

inches in diameter. After being broken it is carried by an elevator to the hopper of the mill stones and ground as fine as possible. The stones used are usually French Burr stones about 4 feet 6 inches in diameter, driven at a speed of from 120 to 130 revolutions per minute. The quantity of cement turned out by a good pair of stones should be not less than a ton and a half per hour. Some manufacturers return to the mill-stone,by an elevator and endless belt or some such arrangement, the coarser particles which will not pass through the sieve after the grinding process, while others trust to their millers to grind within certain limits.

After the cement is ground it is passed into the store by means of barrows, endless bands, or archimedean screws, and remains there until it is wanted, when it is filled into sacks or casks according as it is required for home or foreign consumption and it is then ready for transit.

Difficulties in Securing a Uniform Product.

On paper, the process of manufacturing cement seems wonderfully easy and simple ; but this appearance is illusory and no one who has not had experience in the manufacture of Portland Cement can know the constant watching necessary and the anxiety and trouble which it entails. The materials are accurately weighed, the weighing machine itself and the weight of the barrows is tested almost daily ; surely the result should be equally accurate. An analysis of several samples of chalk and clay will show that the materials themselves vary largely in their composition, and at different times they contain very different amounts of water ; and it will be easily understood that the weighing of the raw materials does little more than certify that a certain amount of chalk and clay has gone into the wash mill.

In order to make good cement, it is necessary not only to watch the quality of the chalk and clay most

carefully and so alter their proportions as circumstances require, but also to take several samples of the contents of the wash mill during the day, mix them together, and from this mixture take a sample at random, dry it and test it for carbonate of lime so that the average amount of carbonate of lime contained in each day's washing for each wash mill may be known on the following day. This test is by no means a certain one, nor does it insure good cement, but it is a guide by which to work ; and if the temperature of the atmosphere be taken into consideration and the burning of the clinker is carefully carried out, it is a considerable help towards the manufacture of good cement. After each day's grinding a sample of the cement in store from that grinding is measured in a bushel measure and weighed to test the burning. The usual requirement is that cement shall weigh 112 pounds per striked bushel.

Testing the Tensile Strength.

The last step which is necessarily the gauge of excellence of the whole work is the testing of the tensile strength of the manufactured product. To this end samples from each day's grinding and also from each shipment are selected, made into a paste and placed in the moulds laid in water. To the casts thus obtained the name of "briquettes," (little bricks) has been given. They are usually from an inch to two and a quarter inches in diameter, the form varying in different factories. The form of the briquettes considerably influences the results obtained, and the manipulation of them further affects the test. It is the practice to shake the moulds, which are laid on pieces of slate or glass, but this is liable to vitiate the results, since, although it gets rid of the air bubbles it also causes the heavier portions of the cement to settle to the bottom, and renders the briquettes more easy to fracture in some places than in others. When the briquettes are set sufficiently to enable them to be removed from the

moulds they are placed in water and remain there for six days, when they are broken in a testing machine, and the resulting strains are recorded in a book kept for that purpose, and in which also the tests for carbonate of lime and the days on which each kiln is loaded are also entered, so that the test for which any kiln is loaded may be known and also the tensile strength of the cement produced from the kiln.

Testing Machines.

The machines in general use for the testing process are those of DeMichele, Adie and Micaele. Messrs. Fairbanks & Co., of Philadelphia, are paying special attention to the manufacture of testing machines, and are making to the order of CHARLES WARNER & CO., a machine of entirely new design, the latter firm having determined to assure themselves of the quality of the cement they sell, and, with this end in view, they have also fitted out a laboratory for analytical purposes, it being their intention to make a specialty of the cement trade in this city. Thus far, the purchaser has had no other guarantee of the quality of the cement than the honesty of the Agent and the reputation of the manufacturer, and it has often happened in this way that, without the slightest intention on the part of either to practice unfair dealings, very inferior, and even worthless, articles have been sold to consumers to the great detriment of the names of the firms, and no small injury to the cement trade itself. Whatever the construction, the principle of the machine is the same, namely, the gradual application of a breaking strain that can be accurately determined by means of a scale.

Specifications for Cement.

In Germany there is a standard specification for cement ; the test for grinding being that there shall not remain more than 20 per cent. after the cement has been passed through a sieve having 76 measures per linear

inch. For the tensile test the cement is mixed with three times its weight of standard sand, and is tested after 28 days when it must bear 142 pounds per square inch of section.

The following standard of requirements for cement furnished for two large works of public construction in England may be taken as a good index of the quality of the article which the manufacturers are required to produce.

No. 1. Chatham Extension Works.

The cement must be of uniformly good quality, finely ground and weighing not less than 112 pounds to the imperial (striked) bushel. All the cement that does not bear, without breaking, a weight of 650 lbs. upon the test blocks, of $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch section, will be rejected.

No. 2. Metropolitan Board of Works.

The cement shall be ground so fine that the residue on a sieve of 5806 meshes to the square inch shall not be more than 10 per cent. by weight. The cement is to be gauged with three times its weight of dry sand, which has passed through a sieve of 400 meshes, and been retained in one of 900 meshes per square inch. All cement that when neat, sets in less than two hours, must bear without breaking, a weight of 142 lbs. per square inch, and if it takes from two to five hours to set when guaged neat, it shall bear a weight of 170 lbs. per square inch, twenty-eight days after gauging.

Arbitrary Requirements of Engineers and Contractors.

As a matter of fact, the requirements of engineers and contractors are more or less of an arbitrary character, and based on no settled principle to which the manufacturers can apply their tests. One requires a maximum residue of 20 per cent., after passing through a sieve of 2,500 meshes per square inch. Another, that the residue

after passing through a sieve of 5,806 measures to the square inch, shall be not more than ten per cent. One requires that the briquettes shall not break at seven days with a weight of 288 pounds per square inch ; another rejects any cement which breaks with a weight of 400 pounds per square inch. One engineer will specify that cement is to weigh 109 pounds per striked bushel ; another requires it shall weigh 116 pounds, and at the same time be quick setting and have a tensile strength at three days of 150 pounds, at seven days of 400 pounds and at twenty-eight days of 500 pounds per square inch.

Another question on which much difference of opinion exists is that of fine grinding. The general tendency is to insist more and more on finely ground cement, but there can be no doubt that the quality of the cement is the first consideration, and fine grinding the second, although, other things being equal, finely ground cement is worth 40 PER CENT. more than that which is coarsely ground.

Proposed Standard Specification.

With a view to meet the difficulties arising from the want of a uniform standard of quality for the best cement, Mr. Reginald Middleton, an English engineer of considerable reputation, has suggested the following Proposed Standard Specification :

The weight per bushel, after cooling, to be not less than 112 pounds and not more than 118 pounds per striked bushel, the measure 6 inches deep, the angle of inclination 45 degrees, and the length of the board 2 feet, and the fall from the board to the top of the measure 6 inches, the cement being fed from a flat plane at the level of the top of the board into the board. The tensile strength of the test briquettes, seven days after the gauging and six days after the immersion in water to be not less than 335 pounds, and at fourteen days not less than 385 pounds per square inch. All the briquettes to be of a standard

form, and one standard machine to be used for testing. The cement to be ground to such a fineness that, on sifting through a sieve having fifty meshes to the linear inch, the residue shall not be more than 10 per cent.

Cement Manufactories.

With these remarks on the mode of manufacture, testing &c., adopted in English manufactories we may glance, by way of concluding this section, at the aspect and surroundings of a cement manufactory.

We see spots, which, sixty years ago were patches of marsh land and undrained morasses, covered with tall chimneys, many of them upwards of 200 feet high, and surrounded by scores of neatly built cottages in which the operators reside. The wives and families of the men would foot up a population of nearly two thousand, and their wants find occupation for an equal number of artisans and storekeepers.

Each factory is a little world complete in itself. Half a score of miniature locomotives may be seen puffing about at all hours, conveying chalk from the cliff, mud from the barges at the river side, or transporting to the ships at the wharves, thousands of barrels of the manufactured cement. Every article used in the works is made on the premises ; all the repairs are executed by the workmen, even to the casting of brass work for the repairs of the machinery. So great is the stress laid on making these little communities independent of the outside world, that spacious halls for the supply of refreshments to the operatives, and for furnishing them with facilities for social gatherings, rational recreation and the establishment of provident societies and reading rooms, have been erected and maintained by the firms at their own expense, and it may be said as a whole, that there is no class of artisans so thriving and well cared for, as those engaged in cement manufacture.

The results of their labor may not be seen, for the

product is swiftly ferried away to all parts of the world, but a momentary pause on the cliff overhanging the works tells its own tale. Forty years ago this cliff was part of a hill 300 feet high, sloping gently to the side of the river, 200 yards away. To-day, the observer stands on the bank of a chasm 300 feet deep and a quarter of a mile across, dug out in those forty years by the mattock of the cement maker.

The German Cement Manufacture.

The principal seat of the German Portland Cement manufacture is at Itzehoe, near Hamburg, where for many years a flourishing concern has been operated by Messrs. O. F. Alsen & Son. Cement by them has been used with very satisfactory results in the construction of the light house on the island of Amrum in the German Ocean, in the building of the Quay on the Strand Hafen in Hamburg harbor, and in our own country in the construction of the artificial stone foot-walks in the grounds at the Capitol at Washington. In the latter case, Mr. F. H. Cobb, engineer of the Capitol grounds, reported it as a better material for the purpose than any hitherto used.

So admirably has the cement manufactured by Messrs. Alsen fulfilled the expectations of contractors and others, that over 90,000 barrels of the cement were imported during the last year alone, and there can be no doubt that the importations this year will far surpass that quantity.

Recent tests carefully made in this city have satisfied CHARLES WARNER & CO. that for our latitude the Alsen cement is superior to any other.

Cement Making in France.

In France the manufacture of Portland Cement is pursued with considerable success although the exports to this country are neither numerous nor important. Some of the French products are reported to excel the Portland Cement of other countries both in quickness of setting

and in subsequent hardness. Experiments were tried at Havre on hydraulic limes obtained by submitting to a moderate calcination an intimate mixture of nearly pure lime and very fine sand or ground silica in the proportion of 20 to 25 parts of the pulverized silica to 80 of lime. The results showed that the product set under water in 3 or 4 days and acquired a hardness in 22 months superior to that obtained by the Portland Cement.

The hydraulic lime of St. Leger may be taken as a type of French cement. It is composed of sixty parts of clay to one hundred of chalk, or fifty-seven of lime. The chalk is broken up into pieces of the size of three or four inch cubes; it is then placed, with the clay, in a large vertical mill driven by two horses, and both materials are crushed and mixed together with a plentiful supply of water. The semi-fluid mixture is then run off into a series of troughs placed on different levels in which it remains until sufficiently stiff to be made up into balls two or three inches in diameter. When these are sufficiently dry they are calcined in an ordinary lime kiln and then ground up between mill stones for use. The fuel used in this burning is a mixture of coal and coke, which is mingled with the balls in a perpetual kiln. The degree of heat is considerably below that required in burning the Portland Cement.

Natural Cement.

Cement is extensively made in France in the following, among other localities, Vassy, Pouilly, Gutaery (in the lower Pyrenees) and Boulogne-sur-Mer. The last named is an example of the cement manufactured from a natural source. The deposits from which the material is obtained is an argillo-calcareous rock, found in the section of the Oolitic Series, known as the Kimmeridge clay. It is burned and ground up for cement in its natural state without addition of lime, and excellent samples were exhibited in Paris at the Palais de l'Industrie, in 1855.

The paste in the raw material is nearly homogeneous and contains from 19 to 25 per cent. of clay. Instead of using a great quantity of water to separate the materials by levigation, as in the English process, it is merely necessary to add enough to form a plastic paste. Immediately after this paste has passed through the mill, it is shaped into small bricks which are placed in the kiln as soon as they are properly dried. The calcination is conducted at a white heat, for a lower temperature would merely drive off the water and the carbonic acid. The materials must receive a white heat whereby they can become slightly agglutinated. The state of incipient vitrification appears to be the proper limit of calcination. After the operation the pulverulent and scorified portions of the mass are picked out and thrown away.

This cement is of a gray color with a slight tinge of green; it is of a greater specific gravity than the English Artificial Cement and sets more slowly. Its composition is as follows:

Lime	65.13
Magnesia	58
Silica	20.42
Alumina and Oxide of Iron	13.87
	100.00

In one respect it possesses a special value, that of setting slowly, so that it can be used by ordinary masons. In tensile strength however it is far inferior to the artificial product.

Roman Cement.

Although the ingredients of Roman Cement are practically similar to those of Portland Cement and the operation of calcination conducted in a very similar way, it has always been the custom in Europe to apply the term Roman Cement to the product obtained by burning the

natural rock, without any combination or admixture, as opposed to the Portland Cement which is a purely artificial product.

As already stated in a previous section, there is abundant evidence that the Romans were well acquainted with the manufacture and properties of hydraulic cements. In Britain they appear to have used the material which still forms the basis of the Roman Cement manufacture in England, viz.: the nodules of argillaceous limestone found abundantly in the London clay formation throughout the County of Middlesex, and at Harwich on the coast of Essex. These nodules technically called "septaria," consist of concretions formed around a nucleus, commonly the fossil of a marine animal and they contain a notable proportion of sulphate of lime, the basis of what is called Plaster of Paris

In France a similar material is found at Boulogne-sur-Mer, and in Italy where it was also used by the Romans and is still extensively used under the name of Pozzuolana. This name is properly applied to a substance of volcanic origin originally discovered at the foot of Mt. Vesuvius near the village of Pozzuoli. It is largely quarried in the vicinity of Rome and Civita Vecchia in Italy, and in the Puy-de-Dome, Upper Vienne, Upper Loire, Cantal and Vivarais, in France. Its value for purposes of construction, in combination with rich lime, has been known for many centuries, and Vitruvius and Pliny both speak of its admirable properties as exhibited in the marine constructions of the Romans, extant in their day. In modern practice, the Italians add sand as well as lime to the Pozzuolana, for the purpose of increasing the hydraulicity of the cement.

The "Trass" of the Rhine Valley, in Holland and the "Arenes" of the Department of Dordogne, in France, are natural Pozzuolanas and used for the same purposes.

Roman Cement is greatly inferior in tensile strength

and commercial value to Portland Cement, and sets much more rapidly. Some specimens will lose their plastic state, when immersed in water, in one or two minutes, but afterwards proceed very sluggishly in their induration.

We add a letter from George S. Morrrison an Engineer of large experience, and certainly devoid of all prejudice as his letter fully indicates.

OFFICE OF GEORGE S. MORRISON,
CIVIL ENGINEER, 35 WALL STREET,
NEW YORK, July 2d, 1883.

A. C. BABSON, Esq.,

DEAR SIR:—In reply to your enquiries of the 30th ult., I would state that I have used large quantities of Alsen's Cement in the foundations and masonry of the bridges across the Missouri at Plattsmouth, Bismarck, and Blair Crossing, and I decidedly prefer to use Cement of this character in the caissons of pneumatic foundation work and in laying up masonry in very cold weather. The reasons for this preference are based not so much on the results given by experiments made with different varieties of Cement, in the breaking of briquettes and the usual laboratory tests, as upon the ability which this Cement has shown to stand abuse in the work. The Cement is slow setting, and can be used on the first set after delays which with ordinary American Cements make it necessary either to throw away the mortar or to use it on the second set. Experiments made with Alsen's Cement which have been allowed to dry out before hardening, and subsequently wetted, after it had apparently lost all the strength which it ought to have, have shown that even with this extreme abuse the mortar made of this Cement acquired nearly the same strength as if properly handled. Similar results have been observed where Alsen's Cement mortar was allowed to freeze. In the caisson work at the three bridges referred to, I have used large quantities of concrete

above the roofs of caissons in positions where it was desirable to have it obtain the maximum strength in about a week, and this result was given by your Cement. Furthermore, on filling the working chambers of pneumatic caissons I have considered it best to use a concrete consisting entirely of Sand and Cement, without the use of Stone, thus providing a material which could be thoroughly rammed around the caisson and which could be handled with the utmost speed. I have also thought it important to use in this position a concrete which should contain a minimum amount of Cement, so as to get a material which would not be likely to expand or shrink. I have found a concrete composed of four parts of clean sand and one of Alsen's Cement to answer this purpose perfectly, and have filled the working chambers of caissons of 1,300 feet horizontal section in less than three days. While there are many positions in which I believe it to be economical to use the better brands of Rosendale and other American Cements, I consider that the best Portland Cements present advantages in works of the classes described which cannot be found in any of our native Cements.

Yours truly,

GEORGE S. MORRISON.

The Uses of Cement and Concrete.

The uses to which Portland Cement may be put to are various, but it is most extensively employed in the manufacture of concretes, and in this form it serves for the construction of dock walls, retaining walls, piers and jetties, sea walls, bridges, and of houses, ware-houses, dwelling houses, sewers, sewer pipes, flags, tiles, baths, bricks, mantel-pieces, mouldings, and ornamental work generally.

The road-ways of a large proportion of European streets are laid on a foundation of concrete; many sewers are made entirely of concrete, and sewer pipes, which are

far stronger and more water tight than those constructed of stone-ware or fire-clay, are made of the same material, which is also used where fire-proof floors are wanted. Foundations are almost invariably made of concrete, which adapts itself to the irregularities of surface.

Concrete bricks made of breeze and cement in the proportion of 6 of the former to 1 of the latter, and pressed in a hydraulic press, can be made in the morning and built into the work in the evening, and this at about the same price as stock bricks, and they can be turned out in almost any weather.

Houses may be built of concrete laid *in situ*, and they have the advantage of being almost vermin proof, but they also have the disadvantage that they are very hard to pull to pieces and alter.

Concrete may be made into slabs and polished, or it may be used for ornamental mouldings, and cast like metal or clay; and it is exceedingly well adapted for such work, for it takes a very sharp impression, as may be seen by anyone who looks at the face of a concrete retaining wall, where the grain of the timber used in the buiiding will be found exactly reproduced in the cement. Any desired color may be easily given to the concrete through the medium of the aggregate.

Concrete is particularly well adapted for engine and machine foundations, as the engine or machine may be blocked up to its proper position and the concrete cast under it till every cranny is filled and the belts are set perfectly solid in the mass.

Concrete slabs are used for paving foot-ways, and offer a much more even, enduring surface than flags, that is, if they are properly made; and this proviso holds good for all concrete work; it must be properly made, care must be taken that the cement used is of good quality and not liable to blow, that is to say, that it does not contain free lime, that it is properly slaked and that it is

not used in the manufacture of the concrete after it has once set, unless it is reburnt or reground.

A concrete wall will not adapt itself to circumstances as a brick wall will; any settlement will cause cracking, and these cracks are not easily remedied. Hence, failures in concrete walls are common, not because the concrete is faulty, but because sufficient care is not taken to make the foundations secure, and the wall is carried up to its full height in short lengths, whereas, the building should be constructed to as great length as possible at once, but only to a height of 1 foot 6 inches, or 2 feet, and when the next layer of concrete is laid the surface of the last layer should be cleaned and damped and if it has been standing for a long time, it should be dusted with neat cement.

Concrete should be made as required; if it is allowed to set before being put into the work, it is useless, and setting begins very early; some light burned cements, when gauged neat, will begin to set within forty seconds of the time when the water is added and all cements set quicker in hot weather than in cold. The more the cement is agitated, the longer time it will be before it sets and concrete takes longer to set than neat cement, otherwise it would be almost impossible to handle it.

Portland Cement is largely used for stucco, and it often fails and flakes off; this again is caused either by the cement not having been sufficiently cooled off by natural heat, or by the surface of the wall not having been properly damped, causing the previous bricks or stone to absorb the moisture required by the cement.

Improper materials are often mixed with the cement; when sand and gravel are used they should be clean and sharp. Loam, or anything of that nature, kills cement. The admixture of lime with cement should, under all circumstances, be prohibited, for their action in setting is directly opposite and hence the whole tendency is disintegration.

Proportions of Sand and Cement to be used in making Concrete.

The proportions to be used in the manufacture of a concrete must depend entirely upon the work to be done, and the nature of the materials which can be obtained to form an aggregate. We have seen that a proportion of 12 to 1 gives a good result when large masses are used, as in the cases of foundations, dock-walls, piers and jetties built *in situ*; but the sand and stone, or whatever the aggregate is formed of must be sharp and strong; if soft and porous stone and dirty sand be used, a larger portion of the cement will be required. For small work a proportion of 6 to 1 is satisfactory, and this is a strong enough mixture for flags 3 inches thick, if concrete made in the proportion of two parts of well washed granite chippings to one part of cement, be used for the face ½ inch thick. No sand should be used in face work, for if it is present the concrete will wear in holes as may be seen in many concrete walls. Broken slag makes good concrete and so does broken brick; but, whatever be the material used for the aggregate, there must be a sufficient proportion of finer matter, whether this be sand and cement or cement alone, to fill up all interstices and make the whole one mass. The quantity of water to be used in mixing must vary with the materials employed; for instance, broken brick will require more water than granite; and in frosty weather as little water as possible should be used. As concrete sets more rapidly at a high than at a low temperature, and as it will not set safely in frosty weather, it is desirable in the construction of slabs, mouldings, and ornamental work generally, that the temperature during the time of setting should be high, and as even as possible.

Cost of Building with Concrete.

The cost of manufacturing concrete varies very largely in different localities, and depends on the distance the

cement has to be carried, and on the price of a suitable aggregate at the spot where it has to be used; under ordinary circumstances it is much cheaper than brick or stone work of equal strength, so far as the actual material is concerned, but it cannot be used in the same manner; but must be made into bricks or blocks, or cast into a wooden or metal framework of the form of the building or block to be made, and the cost of such frame work must be added to the price of the material and labor. In case of a dock or other large work of that description, the cost of the frame work will scarcely affect the price of the concrete, but when a single house has to be built, special frames must be made, and they will form a large item in the total cost. When, however, the same frames can be used for many buildings, this expense will be greatly reduced. For a single house it is more than questionable whether stone or brick would not be cheaper than concrete, as either is certainly handier to work with.

The field for the use of hydraulic cement is very large, and will unquestionably be still further extended, as greater confidence is placed in the material, which will in its best form outlast stone. There is no doubt but that improvements will be made in the manufacture of Portland Cement, beyond those which have already come into effect, and that both engineers and manufacturers will direct their attention to its perfection and to the extension of its uses.

Miscellaneous Observations.

In many great public works of the present day, concretes formed by mixing Hydraulic Cement with sand and pebbles have been successfully substituted for the more expensive brick work. Within the last few years, a gigantic sewer 19 miles in length and draining upwards of 40 villages and towns in the northwest section of the County of Kent, England, has been constructed wholly of concrete. Many parts of this sewer are laid in beds of running sand

100 feet below surface, the leakage observed being surprisingly small.

Quite recently, two novel illustrations of the value of Portland Cement have been afforded. In one of the cases, a valuable vessel which had been wrecked off one of the West India Islands, was successfully raised and brought into an American port, the hole in her bottom having been filled up by sinking barrels of cement in it. In the second case, the screw steamer Tyne Queen of West Hartlepool, while on a voyage to Drontheim in Norway, struck on a sunken rock, breaking her keel and a number of her plates, and was only saved by the fact that the cement with which her bottom was lined, withstood the thumping which had torn away the plates and rivets.

Resistance Against Fire.

The experience of the last fifteen months has irrefutably proved that the number of materials which may be called fire-proof, namely, will not burn or disintegrate, is limited to a few only. It has been noticed in Chicago, as well as in Boston, that limestones were entirely calcined in many instances, and that granite exploded merely from the radiated heat of neighboring buildings. Again, cast iron, as well as wrought iron, is now known to give way readily. Sandstones, or well-burned bricks, on the other hand, stood heat very well. To these two materials must now be added a third one, namely, cement stone, and it is certainly very gratifying to know that in this respect it is destined to supersede most building stones now in use.

In an address on some effects of the Chicago fire, delivered before the America Institute of Architects, held in Boston, November the 14th and 15th, 1871, Mr. Wight stated, with regard to concrete: "In the *Tribune* building, and the new additions to the court house, the arched floors of corrugated iron seemed to stand the heat remarkably

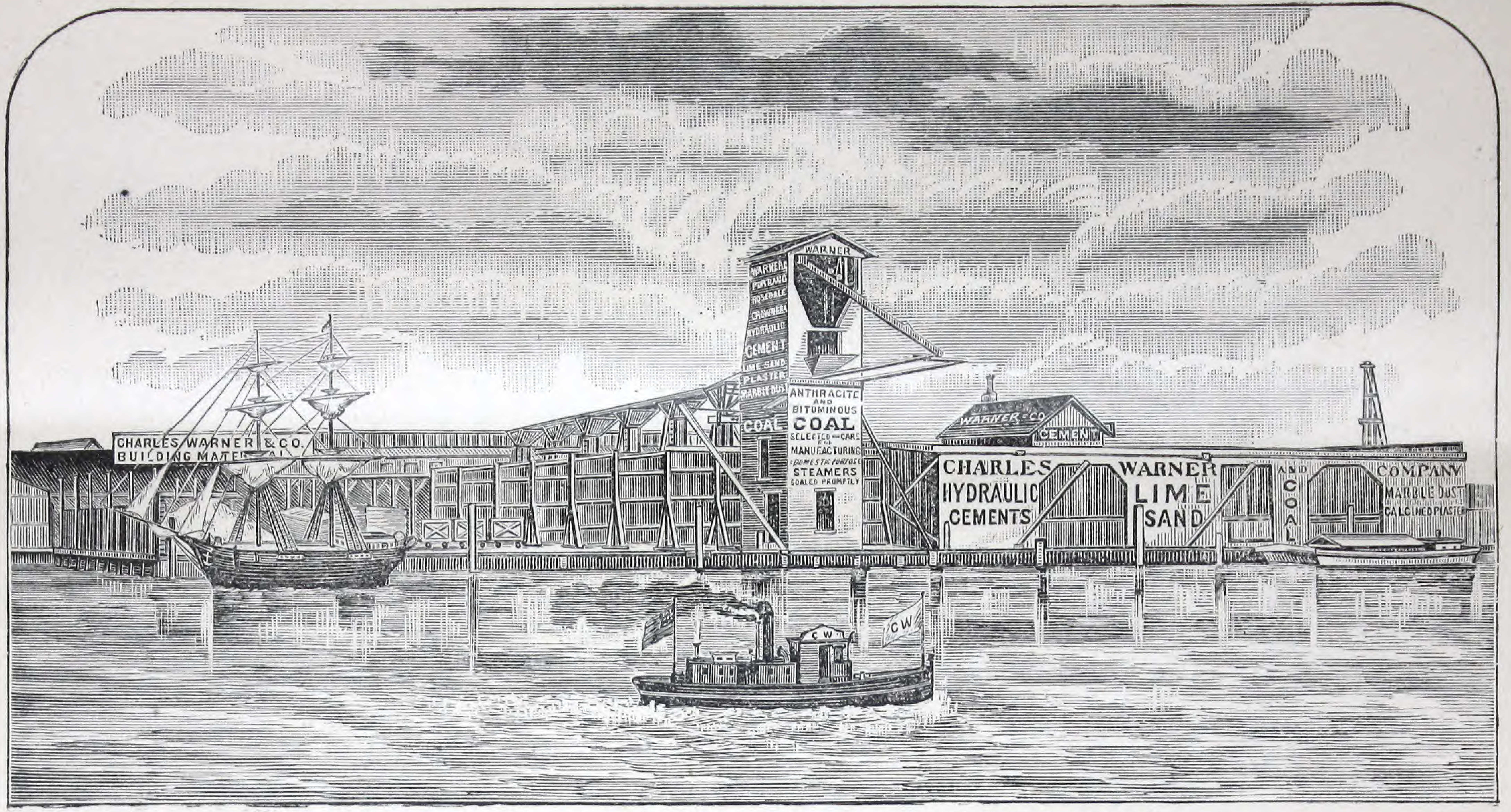
well, and my opinion is, that this is due to the *concrete arch* found in floors thus constructed, rather than to the corrugated iron, the iron being simply a centering upon which this cement had been placed and hardened." Further on, he says: "I can say that the *concrete* arch stood the test remarkably well, and the falling of the floors was in some instances due to the giving way of the beams."

Speaking of an artificial stone, Mr. Wight says: "But I wish to say this, in justice to artificial stone, that there was one building, called 'Farwell Hall,' one of the two or three whose walls stood from the foundation to the top, after the fire, and on one side of that a great deal of artificial stone was used. I don't know whose patent stone it was, but it was used from the second story up to the top, in pilasters, cornices and sills. In many places this stone was scarcely injured at all."

I will mention that this was a Portland cement Stone.

The above facts are corroborated by numerous other authoritative statements. In a report on the character of building materials used in Chicago, prepared by request of the city government, Professor McChesney, the geologist, says: "There is no artificial stone in use equal in all its varied applications for building and architectural purposes to the Frear Stone. I examined its condition just after our great fire, where it had been exposed to as severe tests as any building material in this city; it was neither cracked nor scaled off by the great heat so badly as the real stone used in this city, and on close examination, the heat had penetrated but about two inches in any instance, from which I conclude it might be used to advantages in the construction of fire-proof vaults.

To this I would add that the Frear Stone is essentially Portland cement Stone.



CHARLES WARNER & CO., SOUTH SIDE WHARVES, WILMINGTON, DELAWARE.

CEMENT MAKING IN THE UNITED STATES.

From Colonel Q. A. Gilmore's admirable and exhaustive treatise on the cement manufacture of the United States published by D. Van Nostrand of 23 Murray St., New York, the following interesting particulars are extracted.

Lime stone rocks suitable for the purpose of cement making abound in every part of the United States. They are found notably in the states of New York, New Jersey, Pennsylvania, Virginia, Tennessee, the northern portions of Georgia and Alabama, Massachusetts, Maine, Vermont, Kentucky, Ohio, Indiana, Illinois and Mississippi. In none of these, however, do we find the natural material uniformly developed through the rocks, and combinations become necessary. The exact position of the cement rock in the geological scale is at the base of the Lower Silurian System overlying the Potsdam Sandstone, which latter is interesting in this connection from the fact that it imparts the hydraulic character (by supplying the silica) to the calcareous deposit resting upon it.

The Rosendale Valley.

Prominent among the manufactories of cement in this country, are those of the Newark and Rosendale Cement Company, the Newark Lime and Cement Manufacturing Company, manufactories of F. O. Norton, and the Lawrence Cement Company, and the Lehigh Valley Cement Company; most of which have their location in Ulster County, New York, along the line of the Delaware and Hudson Canal in the valley of Rondout Creek.

The beds of the rock are found occupying every conceivable inclination to the horizon, being sometimes vertical, seldom on the level and ordinarily dipping at a

greater or less degree, either to the north or southeast. The entire region has evidently at a remote period, undergone great geological disturbances, which have been the means of bringing into accessible and convenient positions a vast amount of cement stone that would otherwise have been buried beyond the practicable reach of ordinary mechanical skill. The aggregate thickness of the several layers of this deposit, averages about 46 feet.

No manufacturer makes use of all these beds, and no two of them of the same beds in the same proportion. This is due, principally to those marked variations in the hydraulic character of the stone within comparatively short distances, which constitute a characteristic feature of the deposit. With few exceptions, all the stone taken from the quarry enters into the cement prepared for market.

Outside the Rosendale region, cement factories have been for some years in active operation in the States of Virginia and Maryland, notably at Shepherdstown, Hancock, and Cumberland on the Potomac River, the product finding its way to eastern markets via the Chesapeake and Ohio Canal.

Cement factories are also operated at Balcony Falls, Rockbridge County, Virginia, on the James River, at Utica, Illinois, at Sandusky, Ohio, Kensington, Connecticut, at Louisville, Kentucky, and several points in New York State on the line of the Erie Canal.

Prominent Rosendale Cement Factories.

The Rosendale Cements, on account of the superior facilities and the brisk competition among the manufacturers, have until recently been produced at less expense than any other cement in the country. Of the prominent factories in the Rosendale Valley from which CHARLES WARNER & CO. derive their supplies :—

The NEWARK AND ROSENDALE COMPANY have all their works at Whiteport, six miles from Rondout, and about three miles from the point of delivery to boats below the locks of the canal. They have fifteen kilns of the old pattern and one of Page's Patent. Their grinding apparatus comprises three crackers and four run of five feet stone, driven by steam, and one cracker and three run of four and a half feet stone driven by water. Their quarries are in the immediate vicinity of those belonging to the Lawrence Company, and they make use of the same kind of stone but combined in different proportions. They have from time to time derived their stone from eight different openings, but at the present time, three principally. Two of these are parallel to each other, comprising respectively the upper and lower series of layers, separated by the middle rock, which is worthless in this locality; the third furnishes the upper strata only.

The NEWARK LIME AND CEMENT MANUFACTURING COMPANY is located on the Hudson River at the mouth of Rondout Creek. Its works comprise seventeen cylindrical kilns and a mill driven by steam power, containing five crackers and eleven run of stone of two and a half feet in diameter, and two run of four and one-half feet in diameter. Four of the crackers and five run of stone can grind eight hundred barrels of cement per day.

The cement stone occurs in a continuous bed varying in thickness from twenty to thirty feet and dipping to the northwest from 45 to 75 degrees. It crops out along the eastern slope of a high hill or bluff, at an elevation, in places, of from 150 to 170 feet above the level of the Hudson River. The deposit is reached by five horizontal tunnels, which pierce the slope of the hill near its base at five different points, by means of which the quarried stone is conveyed to the kilns by cars.

There is a marked difference in the quality of the stone in the several quarries as well as among the several

layers of the same quarry, and great care is exercised in distributing the aggregate yield of the entire deposit among the several kilns in order to secure as great a degree of uniformity in the quality of the cement as possible. None of the lower series of cement strata are used by this Company. The upper layers are, in some places, too highly charged with carbonate of lime to admit of their entering into the combination. No attempt, however, is made (and it probably would not be advisable,) to exclude any layer entirely, the skill and experience of the workmen being, in a great measure depended upon to detect and throw out those portions of the stone which might injure the quality of the cement. These generally occur in patches varying from a few inches to several feet in length and breadth, which are recognized by their coarse grained or crystalline appearance or some other characteristic feature. With the exception of these rejected portions, all the upper layers enter into the cement in the proportion of their thickness in the deposit. This Company has a branch at Newark, New Jersey, to which place the stone is conveyed in a raw state. Their cement is second to none in reputation.

A cement of excellent quality, sold by CHARLES WARNER & CO., is manufactured by F. O. NOKTON, at Binnewater, Ulster Co., N. Y. Colonel Gilmore, the leading authority on cement in this country, has published a descriptive pamphlet on the Norton Cement, from which the following particulars are extracted:

The quarries are located at or about the central point of the region which produces the Rosendale Cement and contain all the layers of cement rock that have been found in Ulster County. The upper layers have an aggregate thickness of about 17 feet, separated from each other by the usual middle rock. The kilns, eight in number, are of the usual Ulster County model. They are conveniently located with respect to the quarries, and are connected

with them by a horse railroad, over which the stone is brought and delivered to the top of the kilns. The eight kilns are capable of burning from 650 to 675 barrels of cement daily. The burnt cement, after being drawn from the kilns, is conveyed by a car to the upper story of the "Mill" and there delivered to the crackers. The mill driven by ample steam power contains twelve pairs of mill stones, each 3 feet in diameter. One pair of these stones grinds from 65 to 75 barrels of cement of 300 pounds each, to such a degree of fineness that 93 to 95 per cent. of it will pass through a fine wire sieve of fifty meshes to the linear inch each way.

The productive capacity of these works during a season of eight months is about 140,000 barrels of fine ground cement. The tensile strength as shown by experiment averages about 134 pounds to the square inch. Colonel Gilmore considers this brand of cement equal to any product of the Rosendale factories.

The last of the cements handled by CHARLES WARNER & CO., which will come under notice is that made by the LEHIGH VALLEY CEMENT CO., whose works are located at Siegfried Bridge, Pennsylvania, and is known as "CROWN BRAND" Hydraulic Cement. This cement has been used very extensively during the past ten years throughout Pennsylvania in important Railroad and Canal work, and by very many of the largest manufacturing establishments and was awarded a diploma and medal at the Centennial Exhibition at Philadelphia as the best natural rock hydraulic cement. It is of a lighter color than the Rosendale Cement. A sample one month old tested by W. W. Maclay, C. E, showed a tensile strength of 106 pounds.

We conclude our article on Cement Making in the United States, with a paper written by F. O. Norton, Esq., Fellow of the American Society of Civil Engineers, and

one of the most successful manufacturers of Rosendale Cements in this country.

This paper which follows was read before the Society at its twelfth annual meeting, May 25th, 1880.

"In the course of a large number of experiments made upon the strength of cements, the writer has obtained certain comparative results which he has been requested by a number of the Members of this Society to present at this time.

The experiments referred to were made daily during the season of 1878, at the works of the writer, and show the results from breaking 5,824 test briquettes. The results of a portion of the test work in 1879 are also presented. It may be proper to refer for a moment to the circumstances under which this large number of tests was made.

For many years the manufacturers of the American cements sold under the general name of Rosendale Cement, had permitted the standard of their productions to run very low. There was an active demand for cement, and there was not, until within the last eight years, that care in selection or knowledge of appliances for testing on the part of large users of cement which now, fortunately, more or less exists. The introduction of the foreign Portland Cement, at about that period, afforded an article, of course at a much greater price, but also of decidedly better strength than the low grades of American cement which were really the majority of those then in the market.

Since that time there has been a marked improvement in the quality of the Rosendale cements, effected by care and improved appliances in their manufacture.

The writer knows that a high standard for American cements can be secured, but only by determined effort and careful attention. Unfortunately there is to-day considerable cement of a very inferior quality offered as Rosendale Cement, much to the disadvantage of the effort to maintain a standard of high strength.

The principal deposit of the magnesian lime-stone producing a cement possessing hydraulic energy occurs in the Town of Rosendale, Ulster County, New York. It was first brought into use about the year 1823, in the construction of the locks and other masonry of the Delaware and Hudson Canal, which passes through that county. Its production has gradually increased until there are now made from one million to one million and a half barrels in each season of about eight to nine months, or during the period of navigation on the Hudson River between Rondout and New York. It is the chief industry of a large section of country, its reputation is extended and it is sold in most of the large markets of the United States.

In the management of one of the large works engaged in quarrying and manufacturing this cement, the writer instituted the system of tests referred to, for the purpose of securing uniformity in the product of those works, and of making sure that the standard of the cement made should be what was desired.

These tests were made daily at the works at Binnewater, Ulster County, New York, during the season of 1878, beginning April 1st, and ending November 30th, a period of eight months.

At several times each day a number of test briquettes were made from the cement manufactured during that day. These briquettes were mixed in two ways; namely, for one set the cement was mixed with sufficient water to form an ordinary stiff mortar which was pressed into the moulds with a trowel and smoothed off; for the other set a very dry mixture was made, following the formula adopted by J. Herbert Shedd, member A. S. C. E., in making his experiments. Both mixtures were left in the moulds a few minutes, and were then pressed out with a wooden plunger upon a sheet of tin or sheet iron, and left in the air for thirty minutes; they were then put in water and left in water until broken. The temperature of the

water either for mixing or in the setting tanks was not closely noted, but spring water was used, the temperature of which varies very little during the whole year. In some cases the water in the setting tanks was changed frequently, in some cases very seldom, while some of the briquettes were kept in a flowing spring for twelve months. The results in each of these cases did not materially vary.

From each day's production one briquette of the wet mixture and one briquette of the dry mixture were broken at intervals after the mixing of the briquette, of respectively twenty-four hours, seven days, one month, two months, three months, four months, five months, six months, seven months, eight months, nine months, ten months, eleven months and one year.

There were during the season, the kilns not being drawn on Sunday, twenty-six briquettes of each mixture tested for each of the above periods, including the one year test, or for the eight months of the season's production, 208 tests of each mixture for each of the fourteen periods, making 5,824 briquettes made and broken of the season's production. In other words, there were each month twenty-six days' production, and fourteen briquettes of each mixture each day, giving the total for the eight months of 5,824.

The curves presented have been drawn from the tabulated results, precisely as recorded by the testing machine, with no omissions or alterations. Many briquettes broke low on account of mechanical defects in their construction or from cross-strains resulting from unevenness in their form, probably due in many cases to slight settling of the mortar after removal from the mould and consequent imperfect fitting in the clutch. Some variations in the results are also probably due to inequalities in setting, to the season of the year when the briquettes were mixed, and to the temperature of the

water or air before breaking. Certain individual results shown in the tables are worthy of attention, but of course the main interest lies in the general and average results shown by the curves presented herewith.* These prove conclusively that a cement of high standard strength can be continuously produced in large quantities from the quarries in Ulster County, New York. This, of course, can only be done by proper selection of the stone, and careful attention to the manufacture. Even the mininum results are higher than has generally been supposed practicable averages for Rosendale Cement.

The writer considers these 5,824 specimens, fair samples of the production of the Binnewater works during the season of 1878, amounting to nearly 150,000 barrels of cement.

An incidental result of these tests is of great interest. There has been a general impression that the use of a very small amount of water in mixing cement gave greater resulting strength than when sufficient water was used to form a paste of the consistency of stiff mortar. The tests here recorded prove that the dry mixture does give decidedly higher tensile strength in twenty-four hours after mixture, and that it continues to be stronger than the stiff mortar for some three months. But after that time the reverse becomes true; the curve of strength of the stiff mortar rises to and passes above that of the dry mixture and the strength of the cement mixed as a stiff mortar continues greater than that mixed with very little water, and this is the case continuously thereafter.†

*Tables giving the record of tests for each day, and also monthly plates giving the curves of these tests may be seen at the office of CHARLES WARNER & COMPANY. The publication of these tables of daily tests and the monthly plates is omitted for the sake of brevity.

† The expression, "stiff mortar" does not refer to a thin mortar, but to a mortar made with only such an amount of water as to secure a stiff, plastic paste similar to plasterers' mortar. Water used in excess will certainly weaken the mortar.

The machine used for breaking was built by Riehle Brothers, of Philadelphia, who exhibited its mate at the Centennial Exposition.

During the year 1879, a mould was used producing a briquette of the same form and size as those of 1878, but this mould was made of wood, and was constructed so as to be unlocked and moved away from the briquettes, four of which were formed at the same time.

This obviated the necessity for pushing the briquette out of the mould, and also permitted its remaining in the mould longer than with the metal one. The result has been greater uniformity in the form of the briquette, more accurate fitting in the clutch, and consequently less liability to cross strains. During 1879 the tests were made upon briquettes of stiff mortar only, under the same general method as has been described for 1878. The production of the works during the season of 1879, was about 170,000 barrels. The curve of results of tests of cement made in 1879 upon briquettes up to the age of six months, from this wooden mould shows the advantage of this improved method of forming the briquette. The cement tested is believed to have been of the same general average quality as that of 1878.

Referring now to the general results of the tests of this American Cement as given herewith, and comparing them with the tests of other cements, as for example, the foreign Portland, a comparison can be made as to the effective and economical use of these cements for various purposes.

Very full tests have been made of various brands of Portland Cement, notably by Mr. John Grant, in London, from 1859 to 1868. Results from these tests, running from seven days to seven years, are shown in the accompanying table, which is from the paper of John Grant, Trans. Inst. C. E. London.

Portland Cement.

Age.	Neat cement, average breaking test of ten experiments. Lbs. per square inch.	One of cement to one of sand, average breaking test of ten experiments. Lbs. per square inch.
7 days	363.1	157.0
1 month	415.9	201.1
3 months	469.3	243.3
6 "	522.9	284.6
9 "	542.0	307.7
12 "	546.5	317.6
2 years	588.8	351.2
3 "	584.2	348.8
4 "	583.4	363.6
5 "	580.4	364.9
6 "	581.3	364.2
7 "	589.9	383.8

The strength of Portland Cement, unmixed with sand, is, of course very great. It develops a large proportion of its ultimate strength in the first seven days, say from one-half to two-thirds.

Rosendale Cement, of the best qualities, develops great hydraulic energy in twenty-four hours, being at that time equal to the Portland. The Portland then gains very rapidly upon it up to seven days, the difference between the two then being the greatest ; at the end of a month, however, the strength of the Rosendale Cement begins to approach nearer to that of the Portland, and the difference between the two seems to be continually reduced after that time, this referring to mixtures of pure cement.

For practical purposes, however, neither of the cements is generally used without an admixture of sand. The addition of sand to Portland Cement reduces its strength rapidly, as is shown by curves taken from the work on Coignet Beton, by General Q. A. Gillmore, Member A. S. C. E.

This reduction of strength is in round numbers, as follows:

1 part	of sand	gives	mortar	$\frac{1}{2}$	as strong	as pure	cement.
2	"	"	"	$\frac{1}{3}$	"	"	"
3	"	"	"	$\frac{1}{4}$	"	"	"
4	"	"	"	$\frac{1}{5}$	"	"	"
5	"	"	"	$\frac{1}{6}$	"	"	"

The reduction of strength of Rosendale Cement by the admixture of sand seems to be somewhat less. The strength of a mortar formed by the mixture of one portion of Rosendale Cement with one portion of sand has been tested, and the result of these tests is shown in the Plate on page 48. The strength of the mortar of Portland Cement in the proportion of one of cement to two of sand is, at the end of six months, say 224 pounds to the square inch, also shown in the Plate on page 48. The strength of a mortar of Rosendale Cement in the proportion of one of cement to one of sand, is at the end of six months, say 257 pounds to the square inch.

Careful experiments made by General Gillmore, and published in the Appendix to the last edition of his treatise on "Limes, hydraulic cements and mortars" gives the quantities of mortar produced from the mixture of cement, sand and water, in various proportions, and using different kinds of cement. Adopting these results, and assuming the cost of the Rosendale Cement at $1.10 per barrel and the best English Portland at $3 per barrel (the market prices May, 1880), and the cost of sand at five cents per barrel, we find that a mortar of Portland Cement in the proportions of one of cement to two of sand* will cost per barrel $1.22.

We also find that a mortar of Rosendale Cement in the proportions of one of cement to one of sand will cost $0.68 per barrel.

* One barrel Portland Cement and two barrels of sand give 2.54 barrels mortar—Gillmore.

Summarizing the comparison, we find that a mortar of Rosendale Cement in the proportions of one of cement to one of sand has a tensile strength of 257 pounds to the square inch, and costs $0 68 per barrel; and that a mortar of foreign Portland Cement, in the proportion of one of cement to two of sand, has a tensile strength of 224 pounds to the square inch, and costs $1.22 per barrel.

Therefore, the mortar of Rosendale Cement one to one, is 34 pounds per square inch stronger, and $0.54 per barrel less expensive than a mortar of foreign Portland Cement one to two.

This seems to show that for all uses which will be served by a mortar of the tensile strength of 257 pounds per square inch, the Rosendale Cement is economical.

The remaining question is, whether this mortar of Rosendale Cement, one to one, is strong enough for the practical purposes to which it may generally be applied.

The facts which answer this question are that for fifty years past, and up to within a very short time, *all* the important masonry in this country has been laid with American Cement. The great fortifications on the coast, the Croton Aqueduct, the Boston Aqueducts, both old and new, all the government dry docks, the light-houses, the locks, culverts and aqueducts on the Erie and other canals; all the masonry of railroad bridges, viaducts and culverts, the sewers of our cities, the masonry of our gas-works, many hundreds of miles of wrought iron water-pipe lined and laid in cement; the mills and mill dams in various localities; in fact, nearly all the masonry built under water and out of water in the United States up to within a few years has been constructed with American Cement.

The standard of strength for American Cement during most of these years past, was not as high as it now is, and only in specially important situations was the mortar made as rich as one to one.

The result of this use of American Cement has been very generally satisfactory. As a proper economy in the use of the materials of construction is one of the essential elements of good engineering, the writer has ventured to submit these somewhat extended tests, made originally entirely because he believed that, as a manufacturer of cement, it would be in all respects advantageous to improve its quality and maintain a high standard for its strength. He has ventured also to present to the Society, some deductions which seem to fairly follow the results of the tests.

In commendation of F. O. Norton's Cement,an article introduced by CHARLES WARNER & CO. in this city, we add the following letter from F. A. Mahan, Capt. Engineers, U. S. Army.

DAVIS ISLAND DAM.

U. S. ENGINEER'S OFFICE,
PITTSBURG, PA., July 16th, 1883.

My Dear Sir :

You asked me some time ago for a certificate of character as to your special brand of Rosendale Cement. This I give with great pleasure.

Since the Davis Island Dam has been in course of construction we have received from you, in all, thirty-two thousand five hundred and forty-eight (32,548) barrels of cement.

This cement was adopted, after a careful examination into the merits of many other kinds both natural and artificial, as being the one best adapted to the work from the two points of view of efficiency and cost. It has been used in many different ways, as mortar, as concrete, and as grout, and in all it has given thorough satisfaction. In the case of the concrete I shall give you one illustration :

In the spring of 1881 it became necessary to make a small cut through some concrete which had been laid

during the summer of 1880. This cut was fifteen feet long, eighteen inches wide, and had an average depth of twenty-four inches. It required more than a week's work of one man to make the cut. The concrete was harder than good, firm sandstone. The matrix was so strong that pebbles were cut in two before they would leave their bed. The concrete was composed of twelve cubic feet of broken stone and fifteen cubic feet of sand and gravel mixed, as found in its natural condition in the bed of the river. To the above was added one and a half ($1\frac{1}{2}$) barrels of your cement. The whole was spread and well rammed in six inch layers.

One characteristic of your cement is its thorough uniformity. One lot is almost identically the same as the others. Where work is going on rapidly and the consumption of cement is large (there have been used here as high as six and seven hundred barrels per day,) such a quality as entire reliability is a good one to possess, because the same amount of time does not have to be spent in testing.

Hoping that my testimony may add somewhat to the reputation of your manufacture, I am

Very truly yours,

F. A. MAHAN,

Capt. Engineers, U. S. Army.

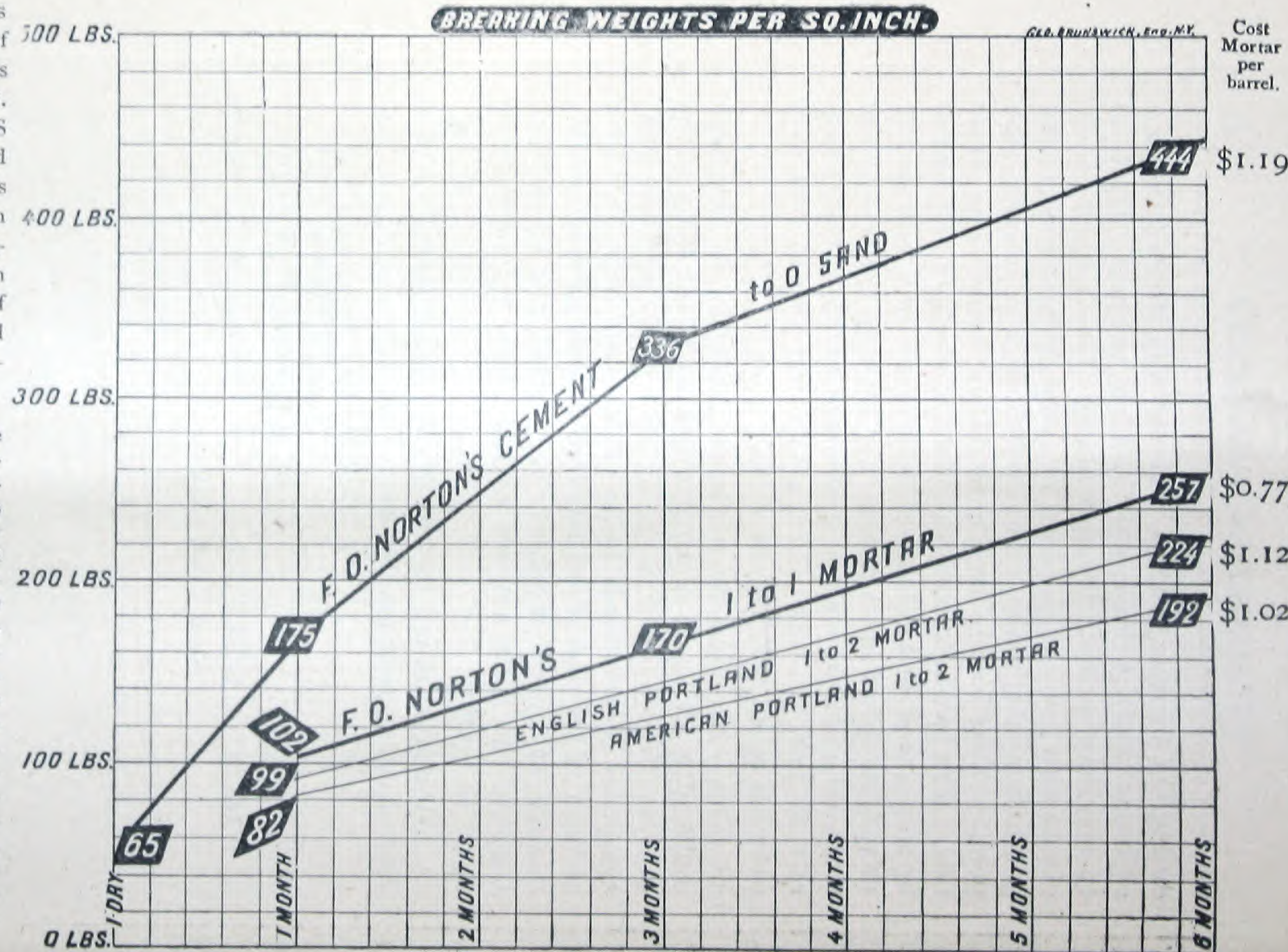
Mr. F. O. NORTON,

New York City.

These Curves give the results of over 3,000 Tests made upon F. O. NORTON'S CEMENT, and the best results compiled from Reports of English and American Engineers, of English and American Portland Cement.

———o———

These results are obtained from a mixture about the consistency of putty as ordinarily used. By using less water and making a drier mixture, the results for the shorter peeiods can be run up to more than double the figures here given. Some engineers in experimenting with Cements, give for publication, results obtained by using a very dry mixture, which, in its nature, is more like Coignet-beton mixture than cement mortar.



DIRECTIONS FOR USING CEMENT.

If disappointment is to be avoided, great care is necessary in preparing CEMENT-MORTAR.

The VESSELS TO BE USED, must be perfectly clean.

The PROPORTIONS of SAND and CEMENT are to be EXACTLY MEASURED :—measure the sand first, pour the exact quantity of cement on it,and mix these well until the mixture shows an even color. And then carefully add the water by degrees, still continuing to work the mixture up, until every particle is soaked with water.

Too much water will lessen the strength of the mortar.

Too little water will prevent its getting hard.

COLD and CLEAN water should be used, hot water impairs strength and color.

The SAND used with the Cement must be SHARP and CLEAN, and FREE FROM LOAM or all earthy substance. If such is not to be had, the sand ought to be well washed out before being used.

ONLY SMALL QUANTITIES OF MORTAR at a time should be prepared, and be used at once. It is most objectionable, by adding more water, to remix mortar, that has become stiff by long standing. Such Cement has begun setting and is worthless.

NEAT CEMENT is used only occasionally for castings, mouldings, where a gush of water has to be stopped, or impermeability to water is desired.

THREE TO FIVE PARTS OF SAND to ONE PART OF CEMENT, according to the quality of the sand, and the strength of mortar desired, are commonly used for common masonry work.

TWO PARTS OF SAND to ONE PART OF CEMENT will be about the right mixture for plastering and for most hydraulic works.

Experience shows that:

I. the larger the proportion of sand, the slower the the Cement-Mortar is setting.

II. in augmenting the proportion of sand, not only the strength and adhesive powers, but also the impermeability of the Cement-Mortar are decreased.

The BRICKS should be well wet before being used. Where Cement is used for facing brick-work, the walls should be first well wet and cleaned, the joints deeply cut out and well sluiced and wet with water.

When the Cement-Mortar has commenced to set, the process ought not to be disturbed.

Bring the Cement-Mortar into complete contact with the whole surface of the bricks, which have previously been well wet. This is indispensable, if disappointment is not to ensue.

The work ought not to be allowed to dry too quick, it should be protected against a scorching sun, and kept moist for some time by being occasionally sprinkled over with water.

The cleaner and sharper the sand, used in mixing the cement, the stronger it will be.

1 cask of Portland Cement, $3\frac{1}{3}$ bushels.

Thickness	1 in.	¾ in.	½ in.
1 barrel of cement will cover	36 ft.	48 ft.	72 ft.
1 barrel of cement and 1 barrel sand will cover, - -	72 ft.	96 ft.	144 ft.
1 barrel of cement and 2 barrels sand will cover - -	108 ft.	144 ft.	216 ft.

Concrete.—1 barrel of cement, 2 barrels clear sharp sand, 5 barrels broken stone or hard burnt bricks or clean gravel, will yield about 20 cubic feet.

Concrete.

Good concrete of Rosendale Cement is made of one part cement, two parts sand, three parts gravel, four parts chips, and is used in these proportions, for foundations, by the officers of the Engineer Corps, United States Army. 1:9

The formula used by many Architects, and by the Engineers of the East River Bridge is, one part cement, two parts sand, four parts chips. 1:6

No Portland Cement, save, perhaps, a few barrels, was used in the foundation of that immense work, the approaches to the East River Bridge, but Concrete made of natural American Cement, chiefly F. O. NORTON'S, was used as foundation for the towers and piers throughout. Both the caissons, supporting the towers on either side of the river, were filled with concrete made from F. O. NORTON'S CEMENT. CHARLES WARNER & CO., *Agents*, Wilmington, Del.

Foot Roads.

1 barrel Portland Cement, 1 barrel clean sharp sand, 3 barrels finely crushed fire bricks or hard common bricks, laid two inches thick on a firm foundation of four or six inches thick of broken stone well rammed, and ground drained well.

Coating Iron Ships.

Equal parts of Portland Cement and clean sharp sand, or finely ground bricks, and laid 1 inch thick.

Sand from Fraland Beach should invariably be used when it can be procured. CHARLES WARNER & CO. have it constantly on hand, and their yard is the only one in the city where two grades of sand know as "coarse and fine" are kept separate.

TABLES OF TESTS.

The following tables showing the comparison in tensile strength, per square inch, of Portland cement briquettes, immersed in water of different temperatures, and dried the last day in the air, are from a paper by William W. McClay, C. E. These experiments have aggregated some 7000 tests and include the principal brands of Portland Cements manufactured in England, France, Germany and in this country.

TABLE 1.

Showing the comparison in tensile strength, per square inch, of Portland cement briquettes seven days old, gauged neat, immersed six days in water of different temperatures, and dried the last day in air.

Temperature of water in which briquettes were immersed.	7 days old. Temperature of the cement paste when briquettes were moulded.								21 days old. Temperature of the cement paste when briquettes were moulded.							
	32 deg	40 deg.	50 deg	60 deg.	70 deg.	80 deg.	90 deg	100 deg	32 deg	40 deg.	50 deg.	60 deg.	70 deg.	80 deg.	90 deg.	100 deg.
	lbs	lbs	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs	lbs.	lbs.	lbs	lbs.
40 deg.	156	147	131	133	113				265	307	236	244	212			
50 deg.	186	206	183	194	143				289		292	260	251			
60 deg.	259	275	245	240	191				348		318	309	282			
70 deg.	299	314	299	286	254				360		403	386	336			

TABLE 2.

Showing the comparison in tensile strength, per square inch, of Portland cement briquettes seven and seventy-four days old, gauged neat, immersed six days in water of different temperatures, and dried the last day in air.

Temperature of water in which briquettes were immersed.	1 week. Temperature of the cement paste when briquettes were moulded.								74 days old. Temperature of the cement paste when briquettes were moulded.							
	32 deg.	40 deg.	50 deg.	60 deg.	70 deg.	80 deg.	90 deg.	100 deg.	32 deg	40 deg.	50 deg.	60 deg.	70 deg.	80 deg.	90 deg.	100 deg.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs	lbs.
40 deg.			187	172	153	180	148	162			278	321	290	363	329	297
50 deg.			230	190	198	198	215	161			290	330	276	352	318	291
60 deg.			244	261	242	244	227	216			310	261	290	339	272	291
70 deg.			250	298	268	265	221	222			272	227	260	324	296	323

TABLE 3.

Showing the average tensile strength, per square inch, Portland cement mortar briquettes, gauged 1 volume cement, 2 volumes sand, 7 and 21 days old.

	1 week.								3 weeks old.							
40 deg.		21	22	20	29					70	52	59	72			
50 deg.		29	26	25	31					73	69	74	67			
60 deg.		38	36	39	28					73	69	67	62			
70 deg.		58	51	39	29					82	71	35	68			

TABLE 4.

Showing the average tensile strength, per square inch, of Portland cement mortar briquettes, gauged with equal volumes of cement and sand, immersed, all but the last day, in water kept at different temperatures.

	1 week.								3 weeks old.							
40 deg.		68	36	28	24	52	91	62		129	106	88	91	111	121	121
50 deg.		93	46	37	39	60	83	73		129	118	98	113	130	122	126
60 deg.		105	64	51	55	68	99	92		137	113	112	114	131	137	133
70 deg.		127	80	79	76	102	102	95		139	94	112	127	136	121	129

TABLE 5.

Experiments being nearly the same as in Table No. 4, showing the average tensile strength, per square inch, of Portland cement mortar briquettes, gauged with equal volumes of cement and sand, immersed, all but the last day, in water at different temperatures.

Temperature of water in which briquettes were immersed.	1 week. Temperature of the cement paste when briquettes were moulded.								3 weeks old. Temperature of the cement paste when briquettes were moulded.							
	32 deg.	40 deg.	50 deg.	60 deg.	70 deg.	80 deg.	90 deg.	100 deg.	32 deg.	40 deg.	50 deg.	60 deg.	70 deg.	80 deg.	90 deg.	100 deg.
	lbs.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
40 deg.			63	72	61	52	91	123			168	132	145	144	128	170
50 deg.			94	94	88	88	110	130			168	147	151	152	135	163
60 deg.			108	122	98	84	77	123			154	173	164	146	160	162
70 deg.			123	140	1.3	102	100	122			173	186	156	154	146	170

TABLE 6.

Showing the difference in mortars gauged with fine and coarse sands, one week and one month old.

1 vol. cement. 1 " sand.		1 vol. cement. 2 " sand.		1 vol. cement. 3 " sand		1 vol cement. 1 " sand.		1 vol cement. 2 " sand.		1 vol. cement. 3 " sand.		Remarks.
Fine sand.	Coarse sand.	Fine sand.	Coarse sand.	Fine sand.	Coarse sand.	Fine sand.	Coarse sand.	Fine sand.	Coarse sand.	Fine sand.	Coarse sand.	
Tensile strength 1 week. Averages from 3 briquettes. Per square inch.						1 month. Averages from 3 briquettes. Per square inch.						
lbs. 85	lbs. 95	lbs. 33	lbs. 63	lbs. 19	lbs. 41	lbs. 162	lbs. 202	lbs 81	lbs 94	lbs. 49	lbs. 74	

We are indebted to Major Samuel Canby, of the Baltimore and Philadelphia Railroad, for the following tables, showing the average results of a series of experiments extending over one year.

TABLE NO. 7,

Showing the comparison in tensile strength, per square inch, of Cement briquettes, rammed into moulds immersed in water from time of setting until broken. 3 to 7 briquettes made from one mixing, excepting Round Top Pure. See note.

	ROUND TOP		COPLAY ANCHOR BRAND		NEWARK ROSENDALE		O. F. ALSEN & SOHN.		KNIGHT, BEVAN & STURGES.		CASEBURNER & LUCAS		IMPERIAL PORTLAND.		ROBINS & CO		BURHAM.		J. B. WHITE & CO.		
Age.	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Time of Setti'g	Tensile strength	Composition.
7 days.	6.5 M.	48.66 lbs	36 M {	61.80 lbs	M {	63.40 lbs	52 M.	343.00 lb	55 M.	264.00 lb	12 M.	212.00 lb	M.	305.5 lbs	20 M.	338.8 lbs	20 M.	333.8 lbs	32.6 M	295.8 lbs	Pure.
14 "	7.2 "	71.00 "		69.83 "	117 "	71.00 "	89.8 "	401.20 "	10 "	330.40 "	23 "	328.8 "		357.2 "			16 "	387.5 "	33.6 "	374.0 "	
28 "							51.8 "	472.00 "	55 "	398.80 "	9.8 "	348.4 "		415.2 "	20 "	422.33 "	20 "	469.6 "	31 "	436.8 "	
319 "			33 "	288.8 "	108 "	277.8 "							The above 24 hours in air before being immersed in water.		(7days						
7 "	6 " {	19.60 "	56 " {	36.85 "	89.8 {	29.83 "	20 "	227.20 "	34.8 "	160.00 "	Dissolved when immersed in water				(97 M.	102.60")	39 "	217.00 "	28 "	151.0 "	1 Cement. 1 River Sand.
14 "		25.50 "		49.50 "		44.33 "		191.20 "	10.6 "	185.80 "					Cracked and partly dissolved		25 "	263.8 "	28 "	186.2 "	
28 "							24 "	322.00 "	31 "	250.40 "								279.00 "	31 "	251.8 "	
7 "	18 " {	17.40 "	63 " {	19.66 "	121 " {	17.30 "	26 "	122.80 "	52.6 "	91.00 "			10 briquettes, Pure, immersed in water when set, swelled or cracked.				Cracked and partly dissolved			81.6 "	1 Cement. 2 River Sand.
14 "		19.80 "		36.00 "		35.50 "	61 "	172.50 "	58 "	105.75 "									61 "	110.4 "	
28 "							55 "	196.75 "	51.8 "	110.00 "									53 "	130.4 "	
7 "	18 " {	8.40 "	44 "	14.17 "	120 " {	16.00 "		88.40 "	69 "	34.75 "									71 "	56.4 "	1 Cement. 3 River Sand.
14 "		12.50 "		23.00 "		21.50 "	76 "	104.60 "	68 "	69.20 "									69 "	86.6 "	
28 "	In making Round Top briquettes Pure set so quick that but one was made from a mixing.						90 "	124.00 "	72 "	75.00 "									66 "	96.2 "	
7 "							179 "	58.50 "		37.00 "										41.2 "	1 Cement. 4 River Sand.
14 "							166 "	69.40 "	108 "	58.00 "									90 "	63.6 "	
28 "								82.60 "	96 "	67.40 "									84 "	63 "	
7 "							186 "	48.20 "	95 "	34.00 "									85 "	28.4 "	1 Cement. 5 River Sand.
14 "							183.3 "	71.00 "	103 "	41.00 "									88 "	41.2 "	
28 "								86.00 "	99 "	60.60 "										51.6 "	
7 "								42.25 "	137 "	24.60 "									101 "	25.8 "	1 Cement. 6 River Sand.
14 "							282 "	62.50 "	121 "	32.80 "									99 "	37.6 "	
28 "							272 "	71.30 "		48.40 "									90 "	43.75 "	
7 "							246 "	38.40 "													1 Cement. 7 River Sand.
14 "							253 "	49.80 "													
79 "								60.40 "													
7 "							264 "	23.75 "													1 Cement. 8 River Sand.
14 "							250 "	34.40 "													
78 "								50.50 "													

TABLE NO. 8,

Showing the pressure required to crack and crush concrete cubes 6 in. by 6 in. by 6 in. The samples were crushed in a hydraulic press. They rested upon a thin layer of moulding sand. Sand was also spread evenly over the top surface of each sample.

PROPORTIONS OF INGREDIENTS BY WEIGHT.

1. part Cement, Alsen & Sohn.
3.63 " River Sand.
.22 " Water.
7.26 " Broken Stone (Brandywine.)

AGE OF.	IN AIR DRY UNTIL BROKEN.				IN AIR WET DAILY UNTIL BROKEN.				IN WET SAND UNTIL BROKEN.			
	CRACKED.		CRUSHED		CRACKED		CRUSHED.		CRACKED		CRUSHED.	
	Total Pressure	Pressure per sq. in	Total Pressure.	Pressure per sq in.	Total Pressure.	Pressure per sq in.	Total Pressure	Pressure per sq. in	Total Pressure.	Pressure per sq. in.	Total Pressure.	Pressure per sq. in.
4 days....	13593.5 lbs	377 6 lbs	21180.5 lbs	614.7 lbs	9800 0 lbs	272 2 lbs	14541 8 lbs	403.9 lbs	7508 9 lbs	208.5 lbs	12645.1 lbs	351 2 lbs
4 days...	13593.5 "	377.6 "	22128.9 "	588.4 "	10748.4 "	298.6 "	17288.9 "	478 6 "	7508.9 "	208.5 "	12645.1 "	351.2 "
4 days....	13909.6 "	386.4 "	2 658 0 "	684.9 "	10432.2 "	289 8 "	15806.4 "	439 1 "	12645.1 "	358 7 "	175 5.0 "	497.7 "
Average	13698 8 "	380 5 "	22655.8 "	629.3 "	10326 8 "	286.8 "	15879.3 "	440 5 "	9220.9 "	285.5 "	14278.4 "	400.0 "
7 days....	10432 2 "	289 8 "	19520 9 "	542.2 "	14541.8 "	403 9 "	17228.9 "	478 6 "	15174 1 "	421.5 "	19204.8 "	533 5 "
7 days...	12329 0 "	342 5 "	6912.7 "	469.8 "	14541 8 "	403.9 "	15806.4 "	439 1 "	13593.5 "	394 0 "	14225.7 "	412 3 "
7 days .	21101.5 "	586.2 "	24974 1 "	693.7 "	19520.9 "	542 2 "	20548.3 "	570.8 "	15806.4 "	439 1 "	19520 9 "	542.2 "
Average.	14587.6 "	406.1 "	20469.2 "	568.6 "	16201.9 "	450.6 "	17861.2 "	496 1 "	14858.0 "	414 8 "	17650.5 "	496.0 "
14 days...	12961.2 "	360 0 "	20864.4 "	579.6 "	21812 8 "	605.9 "	29309 9 "	816.6 "	17545 0 "	487 2 "	19104.8 "	533.5 "
14 days....	17228.9 "	478.6 "	27503.2 "	764.0 "	12961.2 "	360 0 "	16122.5 "	447. "	12645 1 "	351 2 "	19410 9 "	542 2 "
14 days....	18788[illegible]6 "	527 7 "	25922.5 "	720.1 "	17524.1 "	551 0 "	24025.6 "	667.4 "	22603.0 "	627.9 "	26238.6 "	728.8 "
Average..	16326 2 "	455.4 "	24796 7 "	687 9 "	17432.7 "	505.6 "	23182 7 "	643.9 "	17597.7 "	488.8 "	21584.8 "	601.5 "
75 days ...	23709.5 "	658.6 "	41728.7 "	1158 9 "	39515.8 "	1097.5 "	45206.1 "	1255.5 "	38251.3 "	1062 5 "	43941.6 "	1220 4 "
75 days....	24025 6 "	746.4 "	33193.1 "	922.2 "	36038 6 "	1001 2 "	41728.7 "	1158.9 "	32887.0 "	913 4 "	45522.2 "	1264.3 "
75 days....	25290.2 "	702.5 "	31612.5 "	878.1 "	31928 6 "	887 1 "	43309 3 "	1202 8 "	33193.1 "	922.2 "	41728 7 "	1158 9 "
Average..	24341.7 "	702.5 "	35511 4 "	986.4 "	35827.6 "	995 2 "	43414.6 "	1205 7 "	34777.1 "	966. "	43764.1 "	1214.5 "

TABLE 9.

Showing the pressure under which Bricks crack and crush, also the size, weight, and the amount of water absorbed.

Bricks from the Yard of JAS. H. BEGGS & CO.

No.	The process of Manu-facture.	Degree of Burning.	Size of whole brick in cub. ins.	Weight Dry.	Weight after being three days in water.	Gain in Weight.	Percentage of whole weight gained.	Area of Sample Tested.	CRACKED.		CRUSHED.	
									Total Pressure.	Pressure per sq in.	Total Pressure.	Pressure per sq. in.
A 2	Hand-made Paving [Brick							16.40 sq. in.	18967.7 Lbs.	1156 5 Lbs.	50896.4 Lbs	3103.4 Lbs.
" 4	"							15.48 " "	17070.9 "	1102.7 "	1236055 5 "	7984.3 "
" 6	"		66 79	4.703 Lbs	5.218 Lbs.	.516 Lbs	5¾	16.00 " "	64806.0 "	4050.6 "	123289.4 "	7705.9 "
Average									33614 8 "	2103.2 "	99263.7 "	6264.5 "
B 1	Hand-made.	Dark Red.	73 73	4.812 "	5.453 "	.641 "	13½	16 80 " "	34773 7 "	2069.1 "	74289.8 "	4422.0 "
" 2	"	"						16.80 " "	28135.4 "	1668.7 "	79031.0 "	4704.2 "
" 5	"	"						15.99 " "	42677.0 "	2669 9 "	112225.0 "	7018.0 "
Average									35195.3 "	2135.6 "	885 5 2 "	5381.4 "
C 1	Chambers Machine	Hard or Arch						14 63 " "	26554.8 "	1815.0 "	6038 .2 "	4127.1 "
" 2	"	"	66.34	4 890 "	5.265 "	.375 "	7 62-100	16.34 " "	20548.3 "	1257.4 "	105902.4 "	6481 1 "
" 5	"	"						15.17 " "	36354 4 "	2396.6 "	82193 0 "	5418.1 "
" 6	"	"						15.17 " "	36354.4 "	2396.4 "	67967 3 "	4480 3 "
Average									?9952.9 "	1966.3 "	79110.7 "	5126 6 "
D 2	Hand made.	Hard or Arch	68.10	4 969 "	5 406 "	.437 "	8 8-10	15.94 " "	40780.3 "	2558.2 "	107779 1 "	6762.8 "
" 5	"	"						15 60 " "	22128.9 "	1418.5 "	118863.6 "	7619 4 "
" 6	"	"						16.20 " "	40780.0 "	2517.3 "	91676.9 "	5655 0 "
Average									34563.0 "	2164.6 "	106106.5 "	6679 0 "
E 3	Marlins Machine	Hard or Arch	59.42	4 500 "	4.750 "	250 "	5½	12.96 " "	42677 0 "	3292 9 "	74289.8 "	5732.2 "
" 4	"	"						12.90 " "	50 64.1 "	3896.4 "	80612.3 "	6249.0 "
" 5	"	"						14.40 " "	61644.7 "	4280 9 "	75870 4 "	5268 8 "
Average									51528.6 "	3823.4 "	76924.4 "	5750.0 "
F 1	Chambers Machine	Salmon.						17.00 " "	14225.7 "	8 6.8 "	31618.5 "	1859.5 "
" 2	"	"	76.34	4.813 "	5.734 "	922 "	19 16-100	17.22 " "	17387.0 "	1009.7 "	20232.2 "	1174.9 "
" 4	"	"						17 70 " "	13277.3 "	750.0 "	41728.7 "	2357.0 "
" 5	"	"						17 20 " "	15174.1 "	881.2 "	33193.1 "	1929.8 "
Average									15016 0 "	869.4 "	31691.6 "	1830.3 "

Lime.

SECTION 2.

Lime.

Chemistry of Lime. Its affinity for moisture and carbonic acid. Uses in agriculture and the arts. Magnesian lime stones or dolomites. Tests for magnesia. Hints on the slaking of lime.

LIME.

It requires but a moment's reflection to arrive at the conclusion that in a progressive age and a growing community like that around us, there are three minerals on which the pioneers of progress, the engineer and the builder, must be absolutely forced to reply. They are sand, lime and clay.

Chemistry of Lime.

Chemically speaking, lime is the oxide or "rust" of the metal calcium, which belongs to a very interesting group of metals, chemically so called, though not in use as such in the arts. The allied metals are Barium, Strontium and Magnesium. They all occur in nature in the form of sulphates, or carbonates, that is, combined with sulphuric or carbonic acid. The carbonate of lime is

by far the most common, and constitutes the material of probably one-third of the rocks forming the crust of the earth. In this condition it is usually combined with small quantities of silica and iron, but a few rocks consist of carbonate of lime in a state of purity. Chalk is a pure carbonate of lime as is also the shell of the oyster.

The most valuable quality of lime is the property it possesses of parting with its water and carbonic acid at a high temperature and re-absorbing them with great avidity afterwards. Advantage is taken of this property for the purposes of the builder, in the operation known as slaking. Mixed with sand, the paste formed by adding water to the freshly burned lime acquires the properties of a cement and adheres strongly to bricks, stone and other building materials, compacting them into a uniform mass.

There can be no doubt that the nature and properties of lime were known from a very remote period. The Romans made extensive use of mortar in their vast military walls and aqueducts. The great wall from the Tyne to the Solway Firth, dividing England from Scotland and which is a firm substantial fabric to-day after standing a thousand years, was built with stones cemented by a mortar which analysis shows to be precisely similar to the mortars in use in our times. So with the great aqueduct at Seville and the Cloaca Maxima at Rome.

Economic Uses of Lime.

The economic uses of lime outside the department of the builder are numerous and important. In agriculture the judicious application of Lime to the soil is productive of the most valuable results. Modern chemistry has shown that there is a certain combination of the earthy materials of the soil absolutely essential to the proper development of plant life and that these are but seldom found in the soil of any particular locality. There is usually a predominance of one or other of the elements,

silica, alumina, clay, lime ; the triumph of the chemist is shown in his power to give fertility to barren soils by adding a proper proportion of that element in which it is deficient. Thus in limestone regions the lime will be in excess and it becomes necessary to add sand or clay ; in sandy soils the addition of lime is necessary. In other cases there is a deficiency of the vital elements, potash and phosphoric acid, necessitating the addition of guano and manures containing them.

The Action of Lime on the Soil.

The addition of caustic or freshly burned lime to the soil appears to act beneficially in many ways. It tends to break it up and disintegrate it, permitting the air to obtain free access to the earthy matter around the roots of the plant and thus promoting chemical and vital action. Secondly, it sets free the ammonia held in combination and allows the plant to absorb its nitrogenous element with greater facility. It also appears to give the element of warmth to poor soils. But to produce its full benefit it is essential that the lime used should be pure and especially it that it should be free from any considerable admixture of magnesia, a substance which is very abundant in certain limestones while calculated to exert a very injurious effect on the soil.

In selecting limes for agricultural purposes CHARLES WARNER & CO , have been at great pains to choose only such samples as have been shown by analysis to be free from magnesia. The method of estimating the amount of magnesia present in a sample of lime will be referred to further on.

Lime for Whitening and Bleaching.

Another purpose for which lime is largely used is the whitewashing of buildings, fences &c., for the purposes of ornament, cleanliness and sanitation. To make a good lime-white it is of the first importance that the lime itself

should be in the caustic state, free from carbonic acid and combined water, both of which it absorbs very rapidly, even under the most careful keeping. The product of the kilns in its freshest state is sold by CHARLES WARNER & CO., for this purpose.

Lime is of great value to the bleacher and dyer. It is the vehicle through which the bleaching material is conveyed to the fabrics operated on. The compound chloride of lime is prepared by passing chlorine gas into freshly slaked lime. The chloride of lime is extensively used in the bleaching operation in paper mills and for disinfecting purposes.

Again, lime is indispensable to the operations of the alkali works and the glass factory. Its powerful affinity for carbonic acid enables it to withdraw the latter from the alkali liquors. The crude carbonate of potash so obtained is mixed with a paste of water and freshly burned lime and the mixture agitated and suffered to settle in close vessels. The lime absorbs the carbonic acid and falls to the bottom as a heavy white powder, the supernatant liquid being syphoned off and evaporated for use in the manufacture of wood pulp, glass and soap.

In all these operations the use of a pure, freshly burned lime is indispensable if good results are to be attained. There is no economy in cheap or stale lime; it is utterly worthless for manufacturing purposes.

Tests for the Purity of Lime.

The tests for the purity of commercial lime have reference, indirectly to the finding of the amount of water, carbonic acid, and magnesia contained in it, and directly to its powers of slaking and forming a tenacious absorbent paste with water. The tests are, themselves, both easy and simple, and the manipulation within the powers of a person posessed of a very moderate acquaintance with practical chemistry.

The amount of moisture contained in a sample is ob-

tained by crushing a portion, say from a pound to one and one-half pounds, weighing out from 30 to 50 grains contained in a capsule in a chemical balance capable of turning to the one fiftieth of a grain, and noting the loss sustained after the capsule with its contents has been exposed to a temperature of 300 degrees for several hours.

The next step is to determine the amount of carbonic acid contained in the sample. Theoretically a good quality of lime should not contain any carbonic acid, but so eager is the affinity between the two that, in a very short time, the surface of the freshly burned lime becomes covered with a coating of carbonate. If the lime could be kept perfectly dry, this outer crust would form a protection against a further change, but it so happens that the attraction of the lime for water is as greedy as that for carbonic acid. Hence it rapidly absorbs atmospheric moisture, and this acts as a carrier for the carbonic acid, so that, in process of time, the lime returns to its primitive conditions, and its slaking qualities are lost. To ascertain the extent to which the process of deterioration has gone on, in other words, to estimate the freshness and value of the lime, the following process is adopted:

A weighed portion of the sample, usually about 30 to 40 grains, is introduced into a light glass flask especially constructed for the purpose, and the whole weighed in a balance. The flask consists of a bulb, into which the lime is introduced, with a small side tube containing concentrated hydrochloric acid, so arranged that when the side tube is tilted, the acid runs into the bulb, decomposes the carbonate and liberates the absorbed carbonic acid which escapes through a small orifice. As soon as it is seen that no further effervescence takes place on the addition of the acid, the operation is stopped and the traces of carbonic acid remaining in the flask are removed. The apparatus is then weighed. The loss will manifestly indicate the amount of carbonic acid which has been expelled, and of

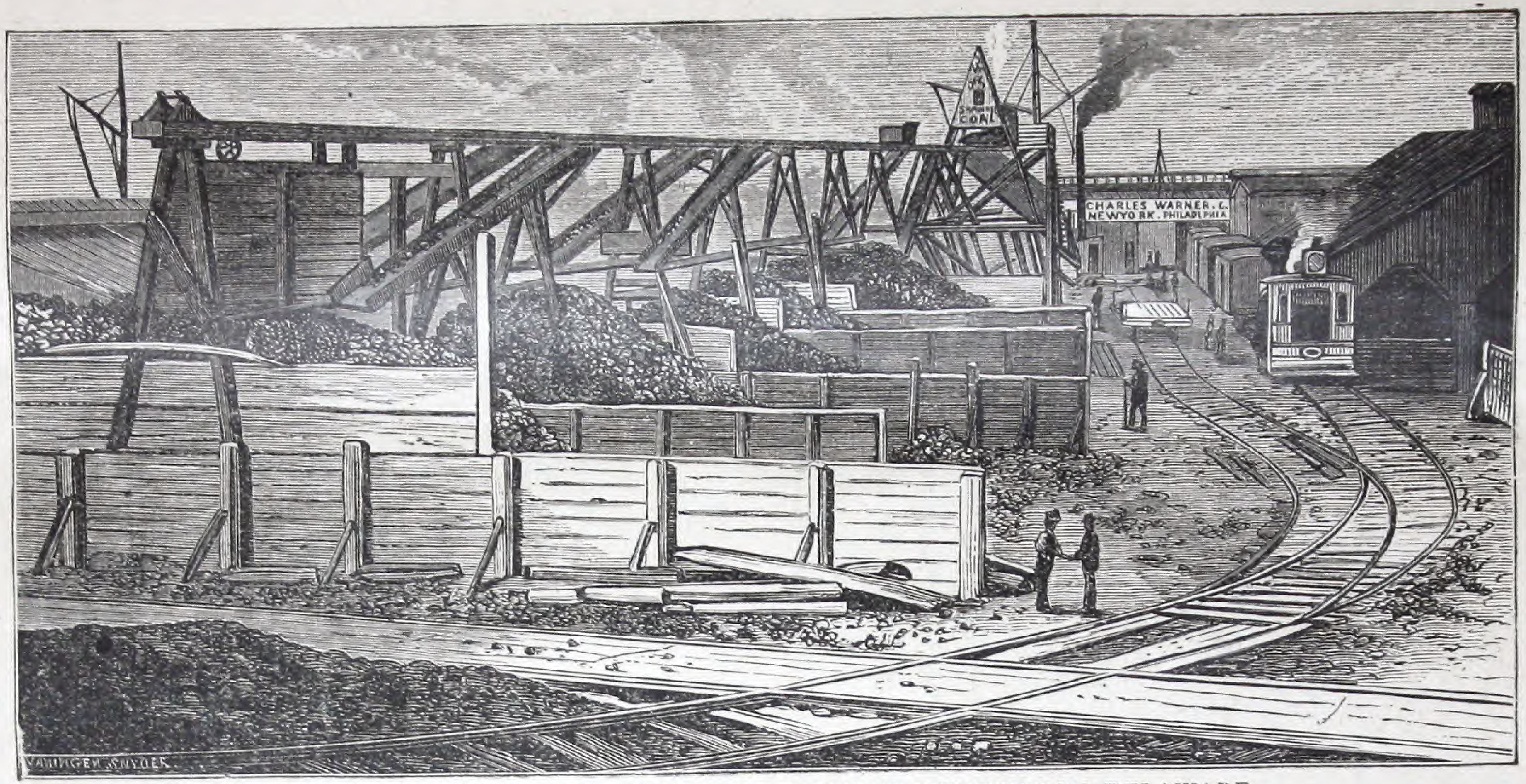
course denotes the degree to which the lime has deteriorated by keeping, or the imperfection of the burning in its preparation. The latter is a very common cause of failure in samples of lime ; over-burning is another.

Magnesian Limestones or Dolomites.

The magnesia present in some samples of lime, results from an inherent defect in the quality of the limestone from which they were obtained. Some limestones, termed dolomites, contain a large percentage of magnesia, and are quite unfitted for the purposes of the agriculturist or the alkali manufacturer. Although the exact determination of the amount of magnesia in a specimen of lime is a matter requiring a careful analysis and great delicacy of manipulation, a fair idea of the value of a sample (as shown by the low percentage of magnesia) may be pretty readily ascertained by noting what portion of it is capable of being dissolved out of a weighed sample by the sulphuric acid. The compound formed by the action of sulphuric acid on lime (sulphate of lime) is nearly insoluble in water : on the contrary, the sulphate of magnesia is exceedingly soluble in water. If, therefore, after treating a sample with dilute sulphuric acid, and filtering the product, the resulting liquid gives a dense white precipitate with ammonia and phosphoric acid, we may be sure that it contains a considerable quantity of magnesia.

Testing for Magnesia.

In laboratory practice the analysis would be conducted in a more systematic manner as follows : A known weight of the sample is introduced into a flask, boiled with hydrochloric acid and evaporated to dryness. The resulting mass, which consists of the chlorides of calcium and magnesia with a little silica, is exhausted with distilled water, and the insoluble silica separated by filtration ; to the clear liquid, oxalate of ammonia is added to precipitate the lime, the latter is collected on a



CHARLES WARNER & CO., AUTOMATIC RAILWAY, WILMINGTON, DELAWARE.

filter, dried, ignited, and weighed as carbonate. From this, the amount of magnesia might be estimated by noting the difference between the added weight of the silica and the lime carbonate so obtained, and subtracting the total from the weight of the sample experimented on.

But the analyst would proceed to weigh the magnesia itself, which he would do in the following manner: The clear solution left after filtering off from the oxalate of lime, contains all the magnesia with a little alumina. A little solution of chloride of ammonia (sal ammoniac) is added to the solution, and a solution of phosphate of soda rendered alkaline with ammonia, is prepared in a separate glass. On mixing these solutions the magnesia falls in combination with the phosphoric acid and is separated by a third filtration. The precipitate is dried, ignited and weighed as phosphate of magnesia, from which the percentage of carbonate of magnesia is derived by a simple calculation.

Lime is usually sent to market in barrels, either in lumps, as it leaves the kiln, or, in the case of the varieties that are more or less meagre, and consequently difficult to reduce to fine pulp by any of the known methods of slaking, in the condition of coarse powder to which it has been brought by grinding. In either case it must be slaked before it can be employed as a matrix for mortar.

Method of Slaking Lime.

Three methods of slaking lime are employed, of which one only is commonly resorted to in the United States. This method is termed drowning, and consists in pouring upon the lumps of lime, collected together in a layer of uniform depth, not exceeding six or eight inches, either in a water-tight wooden box or a basin formed of the sand, to be subsequently added in making mortar, and coated over on the inside with lime paste to render it impervious to water, a sufficient measure of fresh water, previously ascertained approximately by trial, to reduce

the whole to the consistency of thick pulp. Col. Gillmore says, that it is important that all the water required for this purpose (which with different limes, will vary from two and a half to three times the volume of the quick lime) should be added at the outset, at least, before the temperature becomes sensibly elevated.

In this condition the lime will remain entirely submerged, and comparatively quiescent, until after an interval of five to ten minutes, the water becomes gradually heated to the boiling point, when a sudden evolution of vapor, a rapid increase in volume, and a reduction of the lime to pulp ensues.

It is a very common practice on the part of workmen to use either too little or too much water in the first instance, in either case injuring the binding qualities of the lime. In the former case, the lime is brought to a semi-fluid state, so that it cannot become properly incorporated with the sand. If on the other hand too little water is added, and an attempt be made to add more water afterwards when a a portion of the lime is already reduced to powder, the temperature is lowered and the lime chilled, whereby it is rendered granular and lumpy. It is of great importance not to stir the lime while slaking, but to allow it to absorb the water gradually by capillary attraction and its natural avidity for it, taking care that all portions are supplied with it to that degree requisite to produce a paste of slaked lime, and not a powder.

In slaking, the essential point is to procure, if possible the reduction of all the lumps. When the lime is to be used for whitewashing the water should be added at the outset, in larger quantities than specified above, and the whole mass should be run off while hot into tight casks, and covered up to prevent the escape of the water.

These points in the slaking of lime have been mentioned here, because it frequently has been condemned as

of inferior quality, when the fault has really lain at the door of the workmen engaged in the slaking operation.

Relative Quantities of Sand and Lime.

The relative quantities in which sand and lime should exist in mortar depends, in a great measure on the character of the work in which it is to be used; its locality and position with regard to a state of moisture or dryness; and if subjected to alternations in this respect, the character of the moisture, depending on its proximity to, or remoteness from the sea, the nature and magnitude of the forces which it will be required to resist, the peculiarities of the climate, and the season of the year in which the work is to be performed.

It cannot be too strongly impressed upon consumers of lime that, if the full benefit is to be derived from it as a building material, it must be mixed with clean sharp sand as free as possible from any admixture of clay or alumina. It is for this reason that bad results have followed from incorporating it with Kaolin and other materials containing much alumina. Several limes which contain a large percentage of magnesia, have proven very serviceable in the preparation of mortar, but for agricultural purposes and especially in alkali works, the presence of any considerable proportion of magnesia is a serious evil.

We give a short account of the principal limes in commercial use with an analytical table of their chemical constituents :

WRIGHTSVILLE LIME.

This lime from the fact that it increases nearly three times in quantity by slaking and on account of its purity, freedom from Magnesia and insoluble properties, stands at the head of all limes for fertilizing purposes. In March, 1883, CHARLES WARNER & CO. secured an arrangement

with the Pennsylvania Railroad that enabled them to deliver this lime by rail at all Peninsula Stations in competion with Schuylkill limes. The avidity with which farmers availed themselves of this privilege is almost incredible and the orders for the lime have, for the first time in the history of the kilns, been in excess of the production. Extensive preparations are being made to meet the fall demand and the product of the kilns will be about 50,000 bushels per month after September 1st.

For building purposes this lime is second to none; makes a stiff, strong, paste or mortar that will bear more sand than any other lime, and is used by all of the best builders in the city of Wilmington. In color it is a pure white and many plasterers use it for white coating, the only objection to its use in this capacity is that the paste is so stiff that it requires an extra amount of labor to work it.

For this reason the preference is given to the LANCASTER COUNTY LIME of Slaymaker and McIlvain for plastering. These limes are also largely used for brick laying and masonry, their chemical properties forming an excellent cement while when properly mixed in mortar they are so plastic as to be rapidly worked. They are also in demand at the Paper Mills where much rag stock is used.

These quarries were opened in 1832. When the Pennsylvania Rail Road was building and being operated by the State of Pennsylvania, Captain John Slaymaker erected two set kilns and furnished lime and stone that was used in the construction of the road. Before locomotives were used they would haul the loaded cars by horses to a station eight miles distant, on an ascending grade. On the return trip, the horses were put on the cars and carried home by gravity, the trip occupying but a few minutes.

The SHARPLESS LIME, burned near Kennett Square, is a dolomite and combines in a remarkable degree the qualities of the Wrightsville and Lancaster County. It is known among masons as a "Fish Egg" lime, and for this reason is subjected to unjust prejudice, difficult to remove, owing to improper burning of some limes of this character.

The long experience of the Messrs. Sharpless, in burning lime has overcome difficulties that only experience can overcome ; the lime is well and uniformly burned, has many friends and enjoys an enviable reputation for masonry of all kinds, and is largely used with increasing demand. The quarry was opened about sixty years ago, and has been operated continually ever since, during the last fifteen years by the present owners. The product is about 100.000 bushels annually and the supply is inexhaustible.

ROCKLAND LIME ends the list of limes represented by CHARLES WARNER & CO., at Wilmington. It is the purest carbonate of lime known, and is exceedingly valuable in the recovery of Ash from alkali liquors, in wood pulp works and in the manufacture of glass. It is not desirable for masonry but the kilns are worked to their utmost capacity in filling orders for manufacturing purposes.

ANALYSIS OF THE SEVERAL LIMES SOLD IN THIS LOCALITY.

Kiln.	Carb. Lime.	Magnesia.	Insoluble.	Moisture.	Total.
No. 1,	59.5	36.9	3.2	0.4	100.00
No. 2,	51.29	35.29	2.27	10.93	99.78
No. 3,	59.3	40.5	1.8	0.1	101.7
No. 4,	56.5	33.7	11.2	0.4	101.8
No. 5,	98.45	0.36	0.91		99.72
No. 6, (No.1)	97.1	2.6	0.3		100.00
No. 6, (No.2)	80.8	14.7	4.5		100.00

No. 7,	43.26	40.46	5.28	10.99	99.99
No. 8,	54.93	35.63	3.53	6.58	100.67
No. 9,	55.40	35.189	9.411		100.00
No. 10, (No. 1)	70.77	25.50	1.98		98.25
No. 10, (No. 2)	72.73	22.26	3.13		99.12
No. 11,	96.18	1.22	2.60		99.12

No. 1 is from quarries near Lancaster, Pa., operated by Messrs. McIlvain Bros., and George D. Slaymaker, sold by CHARLES WARNER & CO.

No. 2 is from quarries near Lancaster, Pa., operated by Meyers.

No. 3 is from quarries near Kennett Square, Pa., operated by Messrs. C. Sharpless & Son, and sold by CHARLES WARNER & CO.

No. 4 is from quarries near Valley Forge, Pa., operated by Wm. Jones.

No. 5 is from quarries near Annville, Lebanon Co., Pa., operated by John W. Biever, and sold by CHARLES WARNER & CO.

Nos. 6 are from the quarries near Wrightsville, Pa., operated by Messrs. Kerr, Weitzel & Co., and sold by CHARLES WARNER & CO.

No. 7 is from quarries near Norristown, Pa., operated by Mogee.

No. 8 is from quarries near Hockessin, Del., operated by The Jackson Lime & Coal Co.

No. 9 is from quarries near Southwood, Pa., on the Baltimore & Philadelphia Railroad, operated by Nevin.

Nos. 10 are from the quarries near Joanna Station, on the Wilmington & Northern Railroad, operated by J. Plank.

No. 11 is from the quarries near Oakland, Pa., operated by Messrs. Shoemaker & Robinson.

Quantities of Materials Required for Plastering.

100 yards of plastering, laid off work, require 12 bushels lime, 4.375 pounds sand, 5 bushels hair, 75 pounds calcined plaster, 1,670 lath, 9 pounds nails.

100 yards of plastering, three coat work, require 12 bushels lime, 5,000 pounds sand, 2 bushels hair, 75 pounds calcined plaster, 1,670 lath, 9 pounds nails.

Sand.

SECTION 3.

Sand.

Source of the Sand Supply. Fraland Beach. Characteristics of a Good Sand. Analysis. Statistics.

SAND.

The transportation and sale of sand, an article in ever increasing demand for the numerous works of building construction in the state, has attained such proportions as to be quite a trade in itself, and CHARLES WARNER & CO., point with reasonable pride to the fact that the sales of sand from their wharves in the City of Wilmington frequently exceed 200,000 pounds daily.

It is obvious that to obtain a steady supply of so large a quantity of material, two conditions are essential: first, the source must be near at hand, and second, it must be practically inexhaustible. No mere sand hill or sand pit could meet the requirements, because such accumulations are usually of limited area, while the sand is of varying purity and distributed in beds which often pass abruptly into a rock or soil of totally different formation or character. Abundant illustrations of failure of such sources of supply are furnished in the abandoned sand-holes in the

vicinity of Wilmington. Moreover, the modern builder and contractor require a sand of guaranteed purity, as free as possible from organic matter and mud on the one hand and debris on the other. These requirements become imperative when cement is used, as no substance is more detrimental to cement work than impure sand, excepting possibly the admixture of lime with cement.

Fraland Beach.

Such a material is furnished by the beach at Bombay Hook, on the Delaware River, from which the sand sold by CHARLES WARNER & CO., is exclusively derived. Fraland beach, the place in question, was formerly owned by Enoch Spruance of Smyrna, Del., and has supplied the best sand to builders in the City of Wilmington for upwards of forty years. This sand is still preferred to any other offered for sale in the City and contains only 0.05 or one twentieth part per cent. of soluble matter, the remainder being sharp, clean sand, free from all traces of debris or waste matter.

The Johnson Forge Company, of this city, found this sand so valuable for furnace bottoms, that they have directed shipments to be made to Richmond, Virginia, for use in their furnaces located there.

The beach itself is in the form of a crescent, situate near the embouchure of the Delaware River and a little above the head of the Bay. The area is about 19 acres, and as the sand is deposited on this at every tide, the supply is to all intents and purposes inexhaustible, while the quality is uniform.

The exact manner in which the sand thus accumulates at this place is not easily explained, but it may be stated in general terms that it is borne down on the current of the river till the latter meets the rising tide at a point where the formation of the bank favors the development

of an eddy, the sand being deposited while the lighter alluvium and organic matter remain suspended and are carried out to sea. The point is, in fact, a natural triple sieve, in which the very light matter passes through, while the very heavy is arrested at the outset, the medium portion alone being retained.

Analysis shows the sand to consist of;

Pure sand (silica)	98.43
Peroxide of Iron	0.43
Moisture and trace of volatile organic matter	1.14
	100 00

The analyst adds that there was no lime capable of being separated from the silica by acids. The absence of chloride of sodium (salt) is a valuable and distinguishing feature of the Fraland Beach sand.

The Beach was purchased in August, 1882, by CHARLES WARNER & CO., from Lucius P. Campbell, of Duck Creek Hundred, the present owner of the adjoining land. In the fall of the same year (1882), four vessels were employed by the firm in the transportation of sand between Wilmington and Fraland Beach. They have since constructed expressly for the service, two schooners; the "Maud," 65 tons, and the "Sandsnipe of 85 tons. These vessels are constantly employed, making tri-weekly trips, the material being unloaded on a wharf purchased expressly for this branch of CHARLES WARNER & CO'S. trade.

They have also designed, and will soon erect machinery to insure the economical transfer of sand from vessels to cars, to be used, not only for building purposes, but by furnaces located on the lines of railroads that centre at their wharves.

Transportation.

Section 4.

Transportation.

Early history of Wilmington Transportation Lines. Establishment of the Wilmington and Philadelphia Packets. The Electric Line between Wilmington and New York. Its commercial value to Wilmington. Advantages of Wilmington as a transportation center. Its relations to the Peninsula and Coal Fields of Maryland and Pennsylvania.

TRANSPORTATION.

The present excellent transportation service between Wilmington and Philadelphia had its origin as far back as one hundred and ten years ago, in the Colonial days, when packet lines were established between the two ports by the predecessors of the present firm of CHARLES WARNER & Co.

In 1846 the first steam packet, the "E. I. DuPont," was placed on the route, but the enterprise proved premature and was abandoned in the following year. At that time the sloops "Fame" and "Mary Warner", each of about 60 tons burden, were purchased for the line and covered the route making four trips per week until 1866, when they, in turn, were displaced by the barges "Anna" and "Mary" each of about 125 tons burden. These barges were towed by steam tugs, and formed the daily steam line between Wilmington and Philadelphia.

The development of the traffic was such that in 1873 it was found necessary to employ still larger crafts, and the "Coleta" and "Minquas," barges of 250 tons burden, or double the size of their predecessors, were substituted for them, having been built specially for the purpose. By this time the present popular express system of CHARLES WARNER & CO., commenced in 1866, had come into full operation, its peculiar feature being the prompt delivery of parcels, however small, within the city of Wilmington at a charge for delivery equal to one-third the current rate of freight.

It was in 1866 also, that the foundation of the New York transportation service was laid by CHARLES WARNER & CO. The steamship "West Chester" having been purchased of New York parties was placed on the outside, or sea-board route to the Empire city. Like all new enterprises the line was destined to meet with misfortune, and the "West Chester" was wrecked on the New Jersey coast by collision with a schooner.

The Electric Line.

The route remained uncovered till 1870, when the charter of the Wilmington Steamship Company of Delaware, which had passed the Legislature in the previous year, came into force, Wm. M. Baird, of Philadelphia and CHARLES WARNER & CO., being the promoters. In 1870 Mr. Baird sold his interest to CHARLES WARNER & CO., who in turn disposed of a part interest to George W. Bush, Esq., of this city.

The Electric Line is now in active operation and has proven of incalculable advantage to the trade of the City, while realising a moderate profit to its projectors. Indeed it is safe to say that, but for its aid the iron and manufacturing industries of the City, could by no possible means have attained their present development. Not only do the vessels of the Electric Line convey to New York

and thence to Northern and Eastern cities the product of our factories, but in conjunction with the Packet Line to Philadelphia, they furnish the principal means of transportation, between Wilmington and the leading cities of the United States.

An important feature in the development of the Electric Line was the consummation in 1870 of a favorable arrangement between E. T. Warner and the Delaware and Raritan Canal Company, whereby CHARLES WARNER & CO. were enabled to establish a safe line by inland route, thus saving the insurance attendant on the sea passage and allowing them to make use of a class of steamers adapted to the economical transportation of freight between the two harbors, at the same time enabling them to make delivery of shipments of twenty tons or over at any point or wharf in either harbor without adding to the cost, thus saving the cost of truckage or transfer, that was incurred prior to the establishment of the Electric Line.

The advantages of the Electric Line may be summed up in saying that it represents a tri-weekly through line between Wilmington, Del., and the ports of the Eastern States, owned and operated in the interests of Wilmington shippers. There are at present three steamers running on the Electric Line between Wilmington and New York, the "Triplet," "Vesper" and "Annie," each of about 275 tons burden, and a new steamer of about 350 tons is now under construction at the yards of The Jackson & Sharp Co. of this city. The run between Wilmington and New York occupies about 24 hours. The route lies up the Delaware River as far as Bordentown, N. J., 60 miles; thence through the Delaware and Raritan Canal to New Brunswick, 43 miles; and a run through the Sound to New York, about 45 miles further, making a total run of about 148 miles.

The steamers sail from King street wharf, Wilmington, on Tuesdays, Thursdays and Saturdays, at 2 p. m., and

return from New York on Mondays, Wednesdays and Fridays, sailing from pier 15, East River, at 4 p. m.

Wilmington as a Transportation Centre.

In connection with this brief survey of the maritime transportation resources of Wilmington, it will be proper to take a brief glance at the peculiar advantages it enjoys; advantages which it is reasonable to believe are not shared by any other port on the East coast.

In the first place, Wilmington is the true converging point of the Pennsylvania and Maryland coal traffic. Philadelphia is nearer to the former and Baltimore to the latter, but Wilmington is the true focus, as the merest inspection of the map will show.

Secondly, Wilmington is the surplus market of all the coal regions; not a competing, but a surplus market. Hence, any company having surplus coal can dispose of it in Wilmington at a reduced price, and at the same time strengthen prices in other cities.

Thirdly, Wilmington is the only really available point of access to the Peninsula for the Northern and Western traffic. The amount passing by water from points south of the Christiana and across the Chesapeake to Baltimore, is trifling as compared with that which passes over the Peninsula Railroads via Wilmington.

Fourthly, its position on a navigable river, completely sheltered from storms, enables it to retain its position as the leading ship-building station of the east.

Fifthly, it is the natural outlet for the fruit growing and canning industries of the Peninsula. It is the channel through which a large proportion of the Peninsula lumber traffic must necessarily pass, while the proximity of the City to the white oak forests of Delaware, gives a vast impulse to the manufacture of carriages.

In appreciating these advantages and identifying themselves as far as possible with the interest of producers and shippers, CHARLES WARNER & CO. have ever acted in confident assurance of the support of their patrons, a confidence which thus far has been liberally bestowed, and it is hoped justified. It is not difficult to believe that, were the resources of the Christiana further developed by the construction of continuous wharves on the south bank and by proper dredging, the present transportation facilities might be augmented four-fold. Already two leading firms, The Diamond State Iron Co. and The Lobdell Car Wheel Co. have established foundries, shops and rolling mills on the south side of the river. Messrs. C. W. Talley, and George Churchman have erected extensive wharves and CHARLES WARNER & CO. have also made a move in the same direction by purchasing wharves on the south side.

When in the near future the full resources of the Christiana come to be developed by the utilization of the marsh land on the south bank, the dream so ardently cherished by our fathers of a "Road to the River" will become a proud fact, and there is every reason for believing that the nineteenth century will not pass into history without beholding a city of 100,000 inhabitants located between the Brandywine and Christiana.

Coal.

SECTION 5.

Coal.

Nature and origin of coal. Soft and hard coal. History of the Pennsylvania Coal fields. Anthracite. The Lehigh Coal & Navigation Company. Schuylkill and Wyoming Valley Coal fields. The Bituminous coal of Cumberland and Clearfield. The Georges Creek Coal region. Its geological history. Statistics.

COAL.

It is a matter of very general information that the mineral coal consists of the fossilized remains of plants and trees which flourished on the earth at a period incalculably more remote than the earliest human traditions of which we have any record.

It is also well known, that two well marked varieties of coal are found in this country, the Anthracite or hard, formerly known as the Stone Coal, and the Cumberland, and Clearfield, soft, or bituminous coal. The Anthracite gives great heat with but little flame and requires a close furnace and strong draughts for its combustion ; the Bituminous gives much flame, and can be burned in an open fire. Both varieties are found on the slopes of the Alleghany mountains, the Anthracite and Clearfield in Pennsylvania and the Cumberland in Western Maryland.

There are some interesting points of popular science in connection with coal which may be worthy of a brief notice. That it consists entirely of the carbonized remains of plants exposed for ages to heat and pressure, is made quite plain when a fragment is ground extremely thin, soaked in turpentine and placed under a microscope ; the woody and fibrous structure can then be clearly seen. We see to-day in Central America and in Australia precisely the conditions of life in that remote epoch known to geologists as the coal period. Marshes and swamps overhung by huge reeds, and ferns attaining to the stature of trees ; luxuriant vegetation thriving in an atmosphere that would be death to man and the higher animals ; such was the condition of things when the light and heat of the sun were stored up in the leaves and stems of the plants of the Carboniferous epoch for the benefit of ages yet to come. That light and heat we extract to-day in the electric beam, in the blast furnace, in the gas that illuminates our streets, in the coal oil we burn in our lamps. It is the same principle exhibited in different ways, that is all.

The Discovery of Anthracite Coal.

The history of the discovery of the Anthracite coal in Pennsylvania reads like a romance. Though this coal was the first of the American coals to acquire prominence, it was not the first to be discovered or worked in this country. The Bituminous coals of Richmond Va., were the first to be developed, and enjoyed a trade with Philadelphia, New York and Boston as early as 1789, while it had been pretty extensively used in the vicinity of the mines as early as 1775, and during the war of independence was used at Westham, on the James river, five miles below Richmond, for the manufacture of shot, shell &c. It must have been discovered and worked as early as 1750. Tradition says the coal of the Richmond field was first discovered by a boy who was digging for craw fish, as bait, on a fishing excursion.

The first authentic account we find of the practical use of Anthracite coal is in 1768-69, when it appears to have been first used by two blacksmiths from Connecticut, by the name of Gore, who had settled in the Wyoming Valley. The discovery and practical development of coal in the Lehigh region of Pennsylvania were subsequent to its use in the Wyoming Valley; but the coals of the Lehigh region were the first to realize a commercial value in the Eastern Market.

The first discovery of coal on the Lehigh was in the Mauch Chunk or Bear Mountain, a continuation of the Sharp Mountain, about nine miles west of Mauch Chunk, near the site of the present village of Summit Hill. These collieries are to-day operated by the Lehigh Coal and Navigation Company, represented in Wilmington by CHARLES WARNER & CO. The Company found coal in abundance and several tons were dug up, but the question was what to do with it. The nearest market was at Philadelphia, (over a hundred miles distant,) in which mineral coal of any kind was then but little used and Anthracite or stone coal quite a novelty. The intervening region was in a purely savage state, only traversed by Indians and hunters. Col. Weiss, the pioneer in the enterprise who repaired to Philadelphia with samples in his saddle bags underwent every species of ridicule and even persecution in his endeavors to put his treasure on the market.

In 1798 the Legislature of Pennsylvania granted a charter and a Company was formed, which expended $30,000 in improving the navigation of the Lehigh river, by removing rocks from the shoals and constructing wing dams. In 1803 the Lehigh Coal Mine Company built six arks on the river above Mauch Chunk ready for the first freshet to float them to Philadelphia via the Lehigh and Delaware rivers. The coal was hauled from their mines

to the river, some nine miles by horses and the arks started with about 100 tons each, manned by six men. Of the six arks thus started only two actually reached Philadelphia with less than 200 tons of coal which no one would purchase. Experiments made in burning it signally failed, and the enterprise languished for seventeen years.

The first sale of the Lehigh coal was effected in Philadelphia at $21.00 a ton in the spring of 1814, the secret of burning the Anthracite coal having been discovered by accident about two years previously. It was found that by closing the furnace doors, so as to cause the draught to pass through the heated material and not over it, combustion was perfect and an intense heat developed. But still no substantial benefit was derived from the discovery till the year 1820, when the navigation of the Lehigh river was so far improved that during that year 365 tons of coal were shipped to Philadelphia and sold at $8.50 per ton.

From this time the consumption of Lehigh coal increased to an extent little dreamed of by the promoters. In 1864, for instance, the quantity shipped to Philadelphia and other parts, exceeded two millions of tons. In 1832 the navigation of the Lehigh river was still further improved by the construction of the locks and dams. Previous to the year 1847, the Lehigh Company obtained all the coal which they sent to the market from their great open quarry on Mauch Chunk mountain at Summit Hill, and on the identical spot where the coal had been discovered by Philip Gunter.

The Mauch Chunk quarry has naturally been an object of great national interest, and has been visited by admiring thousands. It contains the largest single vein of coal in the world, exceeding in thickness even the celebrated forty feet seam of Dudley in England, and in some parts

being actually seventy feet in thickness, or equal to the combined thickness of the richest coal fields of the Old World. The first quarry was abandoned in 1847. The area it occupied was about 30 acres, and upwards of 2,000,000 tons of coal had been obtained from it.

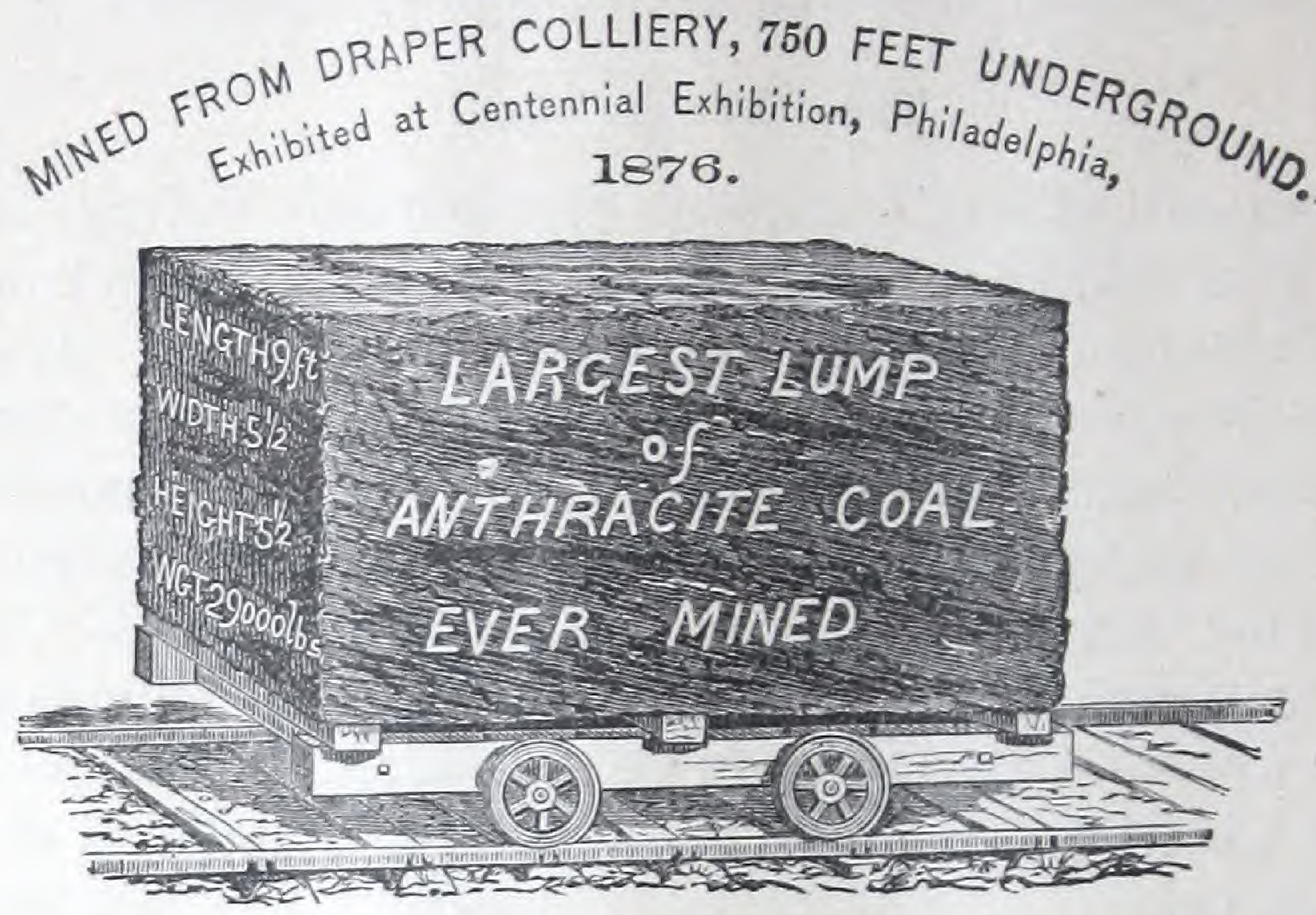
The "Draper" Coal.

Draper Colliery, located in the Mahanoy Valley, three miles from Mahanoy City, Schuylkill County, Pennsylvania, is one among the largest collieries in the region. It was opened in the year 1864, and has been in successful operation ever since; the machinery used for mining, hoisting, breaking and preparing the coal, is of the most extensive character, being the latest and most improved. The principal vein upon this property is the "Mammoth" which averages thirty feet in thickness, and is particularly noted for its hardness. The annual production is about 120,000 tons.

Of the different sizes of coal which this colliery produces, the lump and steamboat are chiefly used by furnaces and foundries in the manufacture and manipulation of iron where strength and durability are essential, and in which the Draper excels. The broken size is used principally by mills and factories, where the coal has gained and maintained the highest reputation for its steam generating qualities. The Egg, Stove, Small Stove and Chestnut sizes are altogether used for domestic purposes and are particularly known and sought for their superior preparation and good burning qualities, which makes the "Draper" one of the leading coals in the market. The Pea size is principally used for Lime burning and generating steam, for which purposes it is peculiarly adapted.

The out-put of this colliery, owing to the superior quality of the coal together with its unexcelled preparation, finds a ready market, and commands the highest prices. At the Centennial Exhibition in 1876, there was exhibited

a lump of coal from this colliery, taken from a depth of 750 feet, said to be the largest lump of Anthracite ever mined, the size of which was, length 9 feet, width $5\frac{1}{2}$ feet, height $5\frac{1}{2}$ feet, and weight 29,000 lbs.



The "Koh-i-noor" Coal.

The Koh-i-noor colliery which has produced the celebrated coal of that name is one of the first Anthracite collieries in Pennsylvania, having produced since its opening 1,500,000 tons of coal of a quality unsurpassed by any other colliery. The opening which was begun in 1868 consists of a shaft sunk through the hardest measures known in the coal region to a depth of 410 feet, where the mammoth vein, 50 feet thick, in splendid condition, was reached. It was only through the aid of diamond drills and the use of nitro-glycerine that Messrs. R. Heckscher & Co., sunk this shaft and completed the openings which presented such difficulties that it was, in the opinion of the best engineers, a very doubtful undertaking. No pumps are used to free the mine of water, and while the most of the other collieries have been, at times, drowned out by freshets, the Messrs. Heckscher & Co., have never had any difficulty in keeping the water out. This is done by two large tanks which hold 1,000 gallons each, and fill and

empty themselves automatically, the full one ascending while the empty one descends. These buckets can be hoisted at the rate of one every 30 seconds, by two engines of 100 horse power each.

The coal is hoisted by two engines of 200 horse power each, and the breaker run by a 100 horse power engine. The coal is dumped directly into the breaker without detaching the drift cars from the cages by means of a self-dumping cage. The breaker is also of peculiar construction and has the largest screens of any in the coal region. The coal is screened differently from any other, and the method is perhaps the best that can be adopted, each size being separated in rotation, commencing with largest, viz., Broken and Egg, so that when the smallest sizes are screened they are free from larger pieces of coal. The screens thus contain only about half the coal at a time that they would have, were the old system of screening the smallest sizes first adopted.

According to the Engineers' estimates there are still 8,000,000 tons of coal in the Koh-i-noor mines. There are in addition to the shaft two slopes from the bottom of the shaft, 750 and 1,500 feet deep to the basin. Shipments of 1,000 tons daily, have frequently been made from the Koh-i-noor mines and between 450 and 500 men and boys are constantly employed. The coal from these mines is a general favorite with housekeepers, and special care is taken to insure its popularity.

The Anthracite coals sold by CHARLES WARNER & CO., are so varied in character as to adapt them to any imaginable use or requirement. Commencing in order of density with the Old Company's Lehigh, Draper, Koh-i-noor No. 1, Koh-i-noor No. 2, Susquehanna coal from Wyoming Valley, Pennsylvania, and Cameron, from Shamokin district, and ending with the Franklin Colliery of Lykens Valley.

The "Lykens Valley" Coal.

The Lykens Valley coal is an exceedingly free burning coal, especially adapted to steam and for burning bricks. It partakes very much of the nature of wood in giving to the brick a uniform red color and has no competition in this field; its value over all other coals for this purpose is generally admitted and appreciated.

For domestic purposes it is not extensively used in the Middle States, but in the Eastern States it is a general favorite and commands an advanced price over the harder coals. As its peculiar qualities become known its usefulness is appreciated and the time is not far distant when the demand for it will exceed the present anticipations of its most ardent admirers.

Cumberland Coal.

The first appearance we have of the Cumberland coal in Maryland was in 1820 when 70,000 bushels were sent down the Potomac in barges and arks, but the opening of the Cumberland district commenced in 1840 when there were shipped over the Baltimore & Ohio Railroad 1,708 tons. We find no shipment by the Chesapeake & Ohio canal till 1850 when 3,042 tons were transported over that route.

The Cumberland coal region in Maryland belongs probably to the great Alleghany coal fields though separated from the great body of that coal field by the axis of the Negro mountain. Most of the coal mines in Maryland are in the Georges Creek region, which is about five miles wide by thirty miles long, covering an area of 150 square miles. The coal in this region may be said to lie in three basins and undoubtedly once formed a continuous stratum, but a considerable portion has been removed by erosion, a term applied by geologists to the wearing away and and removal of soil or rock by water.

The great basin extends on the northeast to Pennsylvania and in the South into Virginia. The distance through

Maryland is about twenty miles. It is convex shaped or an oblong basin rising slowly to the north and south along the strike of the seams of the common centre near the mouth of the Georges Creek, or its confluence with the Potomac and more rapidly east and west or to the outcrops of the seam on the face of the Great Dan and Savage mountains. The rise of the Georges Creek from its mouth near Piedmont to its source near Frostburg is about 1100 feet.

It may be regarded as a grand manifestation of the prescience of omnipotence, that the deep ravines and gorges penetrating the coal fields, and whose streams still wind through the vast mountains, they in part washed away, have enabled a man to obtain access to supplies of coal which in no other way could have become accessible to him. But for the upheaval of the Alleghenies and the subsequent penetration of the region by the streams which to-day run through them, the mass of material buried thousands of fathoms deep by the layers of other rocks deposited in after ages would have forever remained unknown, like a treasure ship buried in the depths of the mighty ocean.

Georges Creek Coal.

Since August, 1882, CHARLES WARNER & CO., have been supplying their customers with semi-bituminous coal from the celebrated "Jackson" mine, located in Alleghany county, Maryland, owned and worked by the American Coal Company, and although prepared by previous knowledge of the reputation of this coal for satisfactory results, they have been more than justified in their selection of this particular coal, by the universal commendation it has received.

The "Jackson" mine is located in the very heart of the Georges Creek region; the principal vein, and the only one as yet opened and worked, being fourteen feet thick. It is in the mountain range, some 1600 feet above

tide, and extends for about three miles facing on the valley of the Georges Creek. Formerly the coal was lowered by an inclined plane into the cars in the valley below; but in 1879 the American Coal Co., associated with other interests, commenced the construction of the Georges Creek & Cumberland Railroad, running along the mountain side for about twenty miles, ascending from Cumberland to Jackson, and reaching the coal at the outcrop; thus dispensing with the use of planes, shortening the distance carried and lessening the cost of handling and transportation, and at the same time largely increasing the capacity of the workings.

The Georges Creek & Cumberland R. R., also affords a connection, not only with the Baltimore & Ohio R. R., and Chesapeake & Ohio canal, to which routes the product of this mine had been restricted, but with the Pennsylvania R. R., (via its Bedford & Bridgeport division) thus enabling the company to reach markets from which it had been theretofore practically excluded.

The mine has been actively worked since the year 1858, with an unvarying reputation for its product, and with its enlarged facilities and wider market now opened to it, will, undoubtedly, greatly increase its present output.

CHAS. WARNER & CO., also completed arrangements with the New Central Coal Co., in April, 1883, by which they have introduced this truly celebrated coal into this section of the country and thus secure to their patrons, coal from the most desirable collieries in the Georges Creek Region. A peculiarity of this trade is, that CHARLES WARNER & CO., CONFINE THEIR SALES TO SHIPMENTS BY RAIL, and the daily supply that reaches them regularly from the mines, enables them to promptly fill all demands with coal in its full strength. The rapid transit from the collieries protecting it from exposure to atmospheric influences and consequent exhaustion of its most valued

CHARLES WARNER & CO., NORTH SIDE WHARVES, WILMINGTON, DELAWARE.

properties, a loss that is seldom fully appreciated. An acknowledged authority, estimates this loss at five per cent. per month, equal in this locality to twenty cents per ton per month, while other advantages of rail transit add fully twenty cents per ton in favor of that mode of transit. Hence we conclude that railed coal at $3.50 per 2,000 pounds will prove economical to the consumer, when compared with water-moved coal at $3.10 per 2,000 pounds in barges alongside wharf.

The "Morrisdale" and "Cunard" Coals.

The Pennsylvania Bituminous coals with which CHARLES WARNER & CO., are supplying their customers are the "Morrisdale" and "Cunard", mined and shipped by R. B. Wigton & Sons of Philadelphia, a name which has been intimately connected with the coal trade of Pennsylvania during the past twenty-five years.

"Morrisdale" coal is mined and shipped from the Morrisdale Mines, situated in Clearfield county at the terminus of the Morrisdale branch of the Tyrone and Clearfield Railroad.

The miners' houses together with the church, schoolhouse, store and other buildings necessary to so large a business comprise a village having about 1500 inhabitants. All of these buildings and some four thousand acres of the surrounding land, are under the entire control of this firm, which enables them, by their personal supervision, to add many comforts to the miner's none too easy life, and protect him from many temptations which surround him in other places. Their efforts have met with such success that Morrisdale has earned the reputation of being the most desirable home in the region, thus drawing to itself the best class of miners, who, when strikes occur in the region, continue to work feeling assured that justice will be done them.

These mines were the first opened in the Clearfield region, coal having been shipped in January 1870, from

which time the out-put has steadily increased until they now have greater capacity than any working in that district. This continuous increase in shipments most forcibly proves the justness of the well known reputation of this coal for excellence for all purposes to which Bituminous coal is adapted. Throughout New England it has steadily gained favor in competition with coals from other well known regions. In New York, Philadelphia and Baltimore, at the very door of its strongest competitor, it is supplied to steamships of almost every nation.

But perhaps the strongest proof of its qualities is found in the fact that at home, where there is the choice of the many coals from Pennsylvania's various regions, Morrisdale by its merits holds the largest trade.

Cunard coal is mined and shipped by the same well known firm. This mine is located in the Broad Top region on the H. & B. T. R. R. in Bedford Co. This region is in the southern part of Pennsylvania and is separated from the great Bituminous coal fields of that state. It is not only apart in location, but in character differs from the Clearfield coals. The Maryland coals, which are a few miles to the south of this region, so closely resemble Cunard both in appearance and analysis that one might easily be taken for the other.

The Broad Top coals have been long known in the market, having been extensively used before the opening of the Clearfield region ; since that time, however, the workers in iron have given great preference to the latter coals, leaving the former to glass, lime and brick makers, for which purposes they have some advantages ; the large percentage of carbon, and comparatively small amount of volatile matter causing them to ignite more slowly and burn longer. These two coals, different in nature, are unsurpassed within their own spheres, and while either may be adapted to the work of the other, in the economy of the work, their differences should be closely noted by the consumers of fuel.

Coke.

SECTION 6.

Coke.

Chemistry of Coal and Coke.—Methods of Coking.—Connellsville Coal as a Source of Coke.—Statistics.

COKE.

Before proceeding to a description of the process by which coal is converted into coke, it may be desirable to notice briefly the chemistry of coal as a heating agent and the object sought to be gained in the coking process. We have seen that there are two varieties of coal, the bituminous and the anthracite, the former giving great flame, and the latter an intense heat with little or no flame, being in fact, a natural coke or a half way stage between soft coal and coke.

Soft coal may be regarded as a compound of Hydrogen and Carbon in various proportions, some of these combinations being volatile and others fixed. In the bowels of the earth a process of distillation is perpetually going on by which the volatile portions are in part separated as we see in the fire damp or inflammable gas of the mines and the coal oil also distilled in nature's laboratory in coal producing regions. There is one variety of coal known as the Cannel (candle), which is noted for the brilliancy of its light and the ease with which it may be ignited. It belongs to the bituminous class and is very rich in sulphur and volatile hydro-carbons.

In coking coal the object is to drive off the water, the hydro-carbons and volatilize the sulphur, and leave in the coke the fixed carbon, ash and such part of the sulphur as may not be volatilizable. The object to be attained is at the lowest possible cost, to make a coke which shall be silvery with metallic ring, cellular, capable

of bearing a heavy burden and as free as possible from impurities ; a compound of fixed carbon and ash with the coke structures and without water, sulphur or phosphorus both of which latter exert a very injurious influence on iron manufactured from coke containing them.

The Connellsville coal belonging to the Pittsburg coal-bed is especially adapted to the manufacture of coke. It contains about 2 per cent of water, 30 per cent of volatile matter, 60 per cent of fixed carbon less than 1 per cent of sulphur and 8 per cent of ash. One hundred parts of this coal yield 68 of coke containing 87 per cent of carbon combined with hydrogen in such proportions as to yield the greatest amount of heat. This Connellsville coal is bituminous, of a dull resinous luster with seams of bright shining crystalline coal for the most part coated with yellowish silt. It contains numerous partings of mineral charcoal and slate, also small crystals of pyrites (sulphide of iron.) The coal is generally hard and compact.

The Manufacture of Coke.

In the manufacture of coke the first point is to cleanse the coal from any excess of slate and sulphur by a process of crushing and washing, these operations enabling many coals to be made into good coke which otherwise would not have proved satisfactory.

The primitive mode of coking coal in heaps or mounds very naturally grew out of the method employed in making charcoal in conical mounds for furnace use. The plans are essentially the same. The coke yard is prepared by leveling a piece of ground and surfacing it with coal dust. The coal to be coked is then arranged in heaps or pits with longitudinal transverse and vertical flues; sufficient wood being distributed in these to ignite the whole mass. Beginning on a base of 14 feet wide, coal is spread to a depth of 18 inches. On this base are arranged the flues

made of refuse coke and lumps of coal, the coal to be coked being piled up in the intervening spaces and the operation repeated till the heap is of required size. Fire is then applied at the base of each alternate flue. As the process advances the fire extends in every direction until the whole mass is ablaze. Considerable attention is required in managing this mode of coking, in diffusing the fire equally throughout the mass, in preventing the waste of coke by much air at any place and in banking up the heaps with fine dust as the operation progresses from base to top. When the burning of the gaseous matter has ceased the heap is carefully closed in this way.

The final operation is the application of a small quantity of water down the vertical flues which is quickly converted into steam, permeating the whole mass. This gives coke of excellent quality with the least percentage of moisture. The time necessary for coking a heap is from five to eight days. The average yield of coke by this method is about 60 per cent, 24 per cent of the carbon contained in the coal being lost. It is estimated that 1.67 of a ton of coal are required to yield one ton of coke.

The Beehive oven is that generally preferred and is in universal use in the Connelsville Basin. This oven is eleven or twelve feet in diameter and five and a half to six feet high. The working is very simple. The coal is dumped into the oven from a hole in the top and spread evenly on the floor; the front opening is closed with bricks, luted with clay and sufficient opening is left at first to supply the needed air; then after sufficient heat is developed, these openings are closed, and finally the roof opening is closed. The average time of coking is from forty-eight, to seventy-two hours, the latter giving a firmer and better coke than the former. The fire is extinguished by a hose turned on from the top.

In regard to the sulphur which constitutes the chief deleterious ingredient in coke there can be no doubt that

the greatest volume of it exists as bi-sulphide of iron. In coking, one equivalent of sulphur is volatilized leaving the mono-sulphide in the coke. It may also be combined with lime as sulphide of calcium in which case it is more easily got rid of. Unfortunately however, sulphur pretty readily combines with carbon itself at a red heat, hence the disagreeable odor produced when the coke is burned. The compound of sulphur and carbon (di-sulphide of carbon CS_2) is very volatile and inflamable with the air, forming sulphur dioxide (SO_2) a gas of suffocating and most disagreeable odor. There can be no doubt that in the near future some economical and practical method will be found for freeing coke from sulphur.

The last stage of the manufacture consists in breaking up coke by means of a crusher, into sizes known as furnace, egg, stove, small stove, chestnut and pea, thereby adapting it to domestic uses and all the purposes for which anthracite coal is used.

The Advantages of Coke.

The advantages of coke may be summed up in saying that it gives an intense heat, is not liable to "cake" and obstruct the blast when pressed by a heavy weight of superincumbent material, is very economical and when once thoroughly ignited will require very little attention and burn unchanged for hours. A marked piece of coke passed through a furnace 50 feet high in full blast and was taken out but slightly reduced in weight and almost unaltered in form. The enormous thickness of the Pittsburg coal-bed is as astonishing as its exceptional coking character. It yields an average of at least ten to twelve thousand tons to the acre, and even the heavy out-put of the coal needed to supply the coke ovens of the Connellsville regions and years more of such a yield or even an increased one will scarcely affect materially the gross capacity of the basin.

Contents.

Portland Cement.

Cement Making in the United States.

LIME.

SAND.

TRANSPORTATION.

COAL.

COKE.

[BLANK PAGE]

INTERNATIONAL